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Blight Resistance in Pears and Characteristics of Pear Species and Stocks

By

F. C. Reimer

CORVALLIS, OREGON

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SUMMARY

Pear Blight is probably the most destructive disease affecting fruit trees in America. This disease attacks the blossoms, shoots, large branches, trunks and root systems.

The best varieties of American and European pears are susceptible to this disease.

At present the only successful method of combating blight consists in promptly cutting out all the affected parts and disinfecting the wounds. This method is successful when the work is promptly and thoroughly done by experienced workmen. It merely reduces the losses from this disease, however; it does not entirely prevent them.

The losses are greatest when the trunks and root systems of the trees are destroyed. The trunks of our best varieties of pears and a high percentage of the rootstocks used heretofore are susceptible to this disease.

This Experiment Station has assembled practically all the known wild species of pears and most of the available varieties from Europe, Africa, and Asia. During the past ten years this Station has tested these species and varieties for blight resistance. In every species, except the wild type of *P. ussuriensis,* the vast majority of the seedlings blight readily in the young shoots when inoculated.

There is great variation among the seedlings of each of the important species tested; some are very susceptible, while others are highly resistant.

In every species most of the seedlings show a higher degree of resistance in the older wood than in the young shoots. In a few varieties the older wood has been more susceptible than the young shoots.

The European species have proved far more susceptible to blight than most of the Oriental species.

P. communis, which includes the French seedlings and most of the cultivated varieties in America, has proved the most susceptible to blight of all the important species. Not a single immune seedling or variety of this species has been found, although a few varieties and seedlings have shown a very high degree of resistance. When inoculated in the roots 43.8 percent of the seedlings blighted. This species endures shallow and wet soils remarkably well and is resistant to Mushroom Root Rot. It is an ideal stock where root blight is not prevalent.

P. calleryana has shown a higher degree of resistance to blight in the trunks and roots than any of the other species suitable for rootstocks. In this species only 9.1 percent of the trees which were inoculated in the roots blighted, and 5.5 percent of the trees proved immune in all parts of the tree. Young trees on this stock are more vigorous than those on any other species. This appears to be the most promising rootstock for Southern Oregon.

The wild type of *P. ussuriensis* has given a higher percentage of resistant seedlings than any other species. This wild type, however, is of little or no value, due to its exceedingly slow growth.

The seedlings of the cultivated varieties of *P. ussuriensis* rank second only to *P. calleryana* in resistance to root blight. In this group 7.6 percent of all the trees inoculated in the trunks blighted into the roots, and 12 percent of all the trees inoculated in the roots developed the disease. One

variety of *P. ussuriensis,* however, namely, Ba Li Hsiang, showed a higher degree of resistance in the trunks and roots than did *P. calleryana.* In this variety none of the trunk infections extended into the roots, and only 3.9 percent of the root inoculations were successful. Thirty-two percent of the seedlings of Ba Li Hsiang proved immune in all parts of the tree. The seedlings of some varieties of *P. ussuriensis* are highly susceptible to blight. This stock probably will not prove satisfactory on shallow, very heavy, or wet soils.

In *P. betulaefolia* 23.5 percent of the trees inoculated in the roots blighted. In this species 3.5 percent proved immune in all parts of the tree. This species endures more alkali and propagates more readily from root cuttings than any other species of Pyrus. It is well adapted to sandy and gravelly soils.

In the Japanese pear seedlings, *P. serotina,* 23.5 percent of the trees inoculated in the roots blighted. In this species 2.6 percent proved immune in all portions of the tree. This stock will not thrive on shallow or wet soils and is susceptible to Mushroom Root Rot.

In every one of the five most important species of pears we have found some seedlings which are highly resistant to blight and are extremely vigorous. If these trees can be readily propagated from root cuttings or true to type from seeds, they will prove far more valuable than the variable seedlings now available.

In our inoculation work the following, which belong to *P. communis,* have proved the most resistant of the American varieties: Farmingdale, Longworth, and Old Home. These are the most promising for trunk and framework stocks.

Among all the cultivated varieties inoculated in our collection only six have proved immune; namely, Ba Li Hsiang, Chien Pa, Huang Hsiang Sui, Hung Guar, Ma Ti Huang, and Ta Tou Huang. One other variety, Hsiang Sui, has proved very nearly immune. These varieties all belong to *P. ussuriensis* and are of Chinese origin.

In our variety orchard, which is twelve years old, 34 percent of all the varieties have already been killed as a result of natural infection.

The losses from trunk and root blight can be largely prevented in the newer orchards by planting a resistant variety like Old Home on a resistant rootstock like *P. calleryana* or Ba Li Hsiang and topworking them when three or four years old with the desired commercial variety.

Pear Blight is far more virulent under certain climatic conditions than under other conditions. Our inoculation results will therefore not necessarily apply to regions with climatic conditions different from those of Southern Oregon. It is highly probable that our results will not apply, at least in many instances, to the states east of the Rocky Mountains with their humid summer climate.

Blight Resistance in Pears and Characteristics of Pear Species and Stocks

By

F. C. Reimer

PART I. BLIGHT RESISTANCE IN PEARS

INTRODUCTION

Pear Blight *(Bacillus amylovorus)* is probably the most destructive disease of fruit trees in the United States. It is a native American disease and was first reported along the Hudson River in New York state in 1780, and later from all the other pear districts throughout the eastern states. It is now found from Maine to Florida and from the Atlantic to the Pacific. In some eastern fruit districts the pear industry has been wiped out, or reduced to a negligible quantity, and in all of them it has been seriously injured and extensive planting prevented by this disease. At one time there was a profitable pear industry in the southern states, particularly in southern Georgia and northern Florida. The industry was completely destroyed about thirty-five years ago, soon after this disease became established in those states.

Pear Blight was not native to the Pacific Coast. In California the pear industry became established soon after the state was settled and for many years the disease was unknown there. At that time many growers believed pear blight could not develop, or at least flourish, in the dry summer climate of that state. In 1900, however, the disease made its appearance and proved very destructive in the interior valleys. In two years the pear industry of the San Joaquin Valley was practically wiped out. The disease also proved very destructive in the Sacramento Valley, but there, due to great vigilance, the industry has been saved.

In 1906 Pear Blight first made its appearance in the Rogue River Valley of Southern Oregon. Here the disease has proved very destructive and at one time seriously threatened the pear industry. It causes more or less damage every year, and some years is unusually virulent. Here, as in California, the grower must be constantly on the alert to save his trees.

It would be well if we knew just what monetary loss this disease has brought to the pear industry of America, but no such figures are available. The writer believes that a conservative estimate would place the loss above one hundred million dollars.

A narrow belt along the Pacific Coast, including the coastal valleys of Washington, Oregon, and the northern half of California, has remained remarkably free from this disease. It appears in some of these districts from time to time, but has caused comparatively little loss. Just why this is true is not known. It is probably due to certain climatic conditions prevailing in those districts.

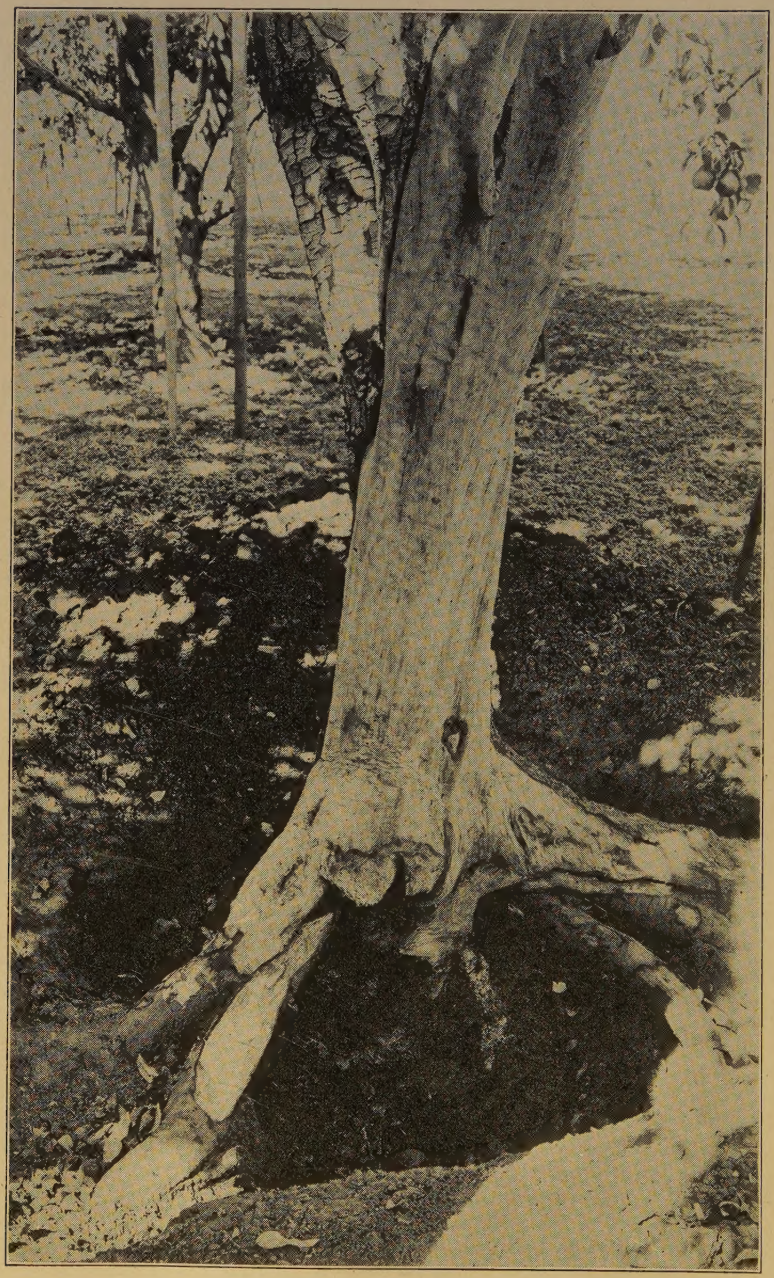

Fig. 1. Bartlett pear tree on French seedling pear *(Pyrus communis)* root treated for bad case of trunk and root blight. A large portion of the bark of the trunk and several roots were removed.

Description of the disease. Pear Blight is so well known and so many complete descriptions of it have been published that a brief discussion of the most important characteristics will suffice here.

Pear Blight is a bacterial disease, caused by a germ scientifically known as *Bacillus amylovorus*. The disease attacks all portions of the tree, including the blossoms, fruit, small and large branches, water sprouts, trunk and root system. When it attacks these various parts of the tree it is often given names which would indicate that several diseases are involved. For example, it is known as "blossom blight," "twig blight," "body blight" and "root blight." These forms of blight, however, are all caused by the same organism. Blossom blight is probably the most common, because the tender flowers are readily infected, the organism gaining entrance through the interior parts of the blossoms where the plant is apparently unprotected and where bees and other insects accidentally deposit the germs during the blooming season.

The organism lives in the delicate tissues of the inner bark. It thrives especially in the tissues of the cortical parenchyma and the cambium layer. Since the bacteria are confined entirely to the region beneath the epidermis, it is impossible to control them by spraying. The bacteria multiply with great rapidity, break down the tissues of the plant, and cause the death of the infected portions.

Pear Blight is most active and develops with greatest rapidity during the spring and early summer months. It is well known that the organism thrives best in tender, sappy, succulent tissues and these conditions usually prevail in the plant during the spring and early summer months. The organism is a minute plant and thrives best under circumstances that are most favorable to the growth of pear trees. During the late summer, fall and winter months, when the plant is least active, the organism either dies out or becomes partly or completely dormant. In many cases the organism dies during the late summer and fall in the smaller twigs, but continues to develop slowly in the inner bark of the larger branches, and in the trunk and root system. This, however, is only a temporary check and as soon as favorable conditions are renewed it again develops and progresses with great rapidity.

During the winter months the disease usually harbors in the inner bark of the older and larger portions of the tree, such as the root system and trunk, and in cankers on the larger branches. In the spring these infections become active, often producing considerable ooze laden with bacteria, and bees, ants, thrips and flies distribute it to various portions of the tree, where new infections occur.

The most serious phase of the disease, and that chiefly responsible for its dissemination, is the fact that when one blossom becomes infected bees accidentally distribute the bacteria to thousands of other blossoms throughout the orchard in one day. In fact, if it were not for this accidental distribution by insects, blight would not be a serious factor in pear growing.

During rainy seasons, when a tree once becomes infected, particularly in the upper portions, and the disease is washed down and sprinkled over the blossoms and tender shoots, the infection is far more extensive than it is in dry seasons. This was well illustrated in this Valley during the rainy spring and early summer of 1913. If there is little rain throughout the late spring and summer, when the trees are making only a moderate growth, the disease is far less virulent.

Methods of controlling Pear Blight. The present method of controlling Pear Blight is to cut out all affected portions of the tree and disinfect the wounds. In severe cases it is often necessary to remove large sections of the trunk and root system. This method is effective when the work is timely and thorough. It is particularly successful when an entire district follows the plan. Such work is expensive, however, and when a diseased portion is removed the tree is usually injured, since its bearing capacity is reduced. After an orchard has become thoroughly infected, especially where the roots are involved, it is practically impossible to remove every particle of the diseased tissue, since small infections will sometimes be overlooked even by an extremely careful worker, and the most experienced and skillful blight cutter often finds it difficult to decide how far he must cut in order to remove all traces of the disease. This is particularly true of the Bosc tree during the active growing season. In this variety the tissues are often infected for a day or more before they show unmistakable evidence of the presence of the disease.

Furthermore, where the disease is very prevalent and thousands of blossoms, in all parts of the orchard, become infected, it is almost impossible to cut out and destroy every infection. The root systems are often infected for weeks before there are any indications above ground of the presence of the disease. When it is eventually discovered, the root system is often so badly injured that it is impossible to save the tree.

It is therefore evident that this disease is extremely difficult to control. Only the most vigilant growers are successful in doing it.

Resistant varieties. Undoubtedly the most promising method of controlling this disease is through resistance. For many years horticulturists have been seeking desirable types which will resist this disease, but up to this time no such desirable commercial varieties have been found. It is true that during recent years a few have been introduced which do not blight seriously. The most resistant among these are Lincoln, Longworth, German Sugar, Burkett, Kieffer, Old Home, Douglas, and Estella. The fruit of these varieties, however, is of such poor quality that with the exception of Kieffer they have not been extensively planted. Kieffer is a hybrid between the Chinese Sand pear and Bartlett and has proved much more resistant to blight than the standard French varieties. Under certain conditions, however, Kieffer blights vigorously and the fruit is poor in quality.

Lincoln has shown a fair degree of resistance and has been quite widely planted in the Middle West. It is not immune, however, and the fruit is of poor quality. Kieffer and Lincoln can never replace such excellent commercial varieties as Bartlett, Bosc, and Anjou.

It is very evident to all pear growers and horticulturists that we need better resistant varieties of pears than those known at the present time. It is a remarkable fact that among the hundreds of French varieties which have been tested in this country not one satisfactory blight-resistant variety of good quality has appeared. It is also interesting to note that all of the resistant European varieties known in this country are of poor quality. At first thought it would appear that blight resistance in the tree is correlated with poor quality in the fruit. This does not necessarily follow, since the Seckel is of excellent quality and the tree shows more resistance to blight than many which produce inferior

fruit. It is well known that the Seckel is not immune to Pear Blight, and the fruit is too small for an ideal commercial variety.

It now seems improbable that we shall ever obtain the ideal blight-resistant variety, producing desirable fruit, by merely introducing and testing types from other countries. That such varieties can be produced is now evident to horticulturists and plant breeders. The goal can be achieved only through careful selection and extensive breeding. Heretofore considerable breeding work has been done with this object in view, but up to the present time no satisfactory varieties have been produced. This is due to the fact that most of the pear breeders have used for both parents types which were susceptible to Pear Blight. Little progress could be expected from such methods. In some of this work such varie-

Fig. 2. Showing four Chinese varieties highly resistant to blight. Reading from left to right: Ba Li Hsiang, Ma Ti Huang, Huang Hsiang Sui and Hsiang Sui, and four blighted Bartlett trees. These four Chinese varieties were inoculated on four different dates. On each date a Bartlett was inoculated with the same culture. The Bartletts were all killed while the four *P. ussuriensis* varieties remained immune.

ties as Seckel and Anjou, which show a moderate degree of resistance, have been used; but these belong to the common European species, *Pyrus communis,* which is highly susceptible to blight.

Kieffer is probably the most valuable hybrid which has been grown commercially in this country. One of its parents, the Chinese Sand pear, has proved quite resistant to Pear Blight and seems to be well adapted to conditions in the southern states, particularly the Gulf Coast region, but since the tree is tender in the north, and the fruit is gritty, hard, and of poor quality, it is not a satisfactory variety for breeding purposes.

In 1917 and in 1919 the writer found in northern China and Manchuria certain types of pears which will probably become valuable in breeding blight-resistant varieties. These were introduced into this country and a

number of them have proved highly resistant to Pear Blight; some of them produce fruit with certain very desirable characteristics. The fruit is small to medium in size, but has very tender, juicy flesh of fairly good quality, and is free from grit cells with the exception of a few immediately around the core. These varieties are now being extensively used in breeding work at this Station. This work will be discussed under another topic in this bulletin. Experiments of this nature require time, and it may be many years before the ideal variety makes its appearance. In view of what has been accomplished in breeding with other plants and the excellent material now available for this work with pears, the writer believes that the long sought for blight-resistant variety will ultimately make its appearance.

Resistant stocks. Since it will probably require many years to produce the ideal, blight-resistant variety of pears, every possible assistance should, in the meantime, be rendered the grower in preventing and controlling this disease. Pear Blight, as has already been stated, often destroys the larger branches, trunk, and root system of our pear trees. This is because our varieties are susceptible to the disease, and the rootstock which has been used very extensively in the past belongs to *P. communis,* a highly susceptible European species. If our pear trees were all on blight-immune rootstocks a large percentage of the losses now sustained would be prevented. Not only would the root system never be destroyed by this disease, but it would harbor no holdover blight, which is now responsible for so many of the new infections above ground.

Furthermore, if the trees of our standard varieties were supplied with an immune trunk and framework and the disease thus confined to the smaller branches, the present losses would be still further reduced.

During the last thirty years the Japanese pear stock, *P. serotina,* has been extensively used on the Pacific Coast, in the Middle West and in the southern states, and a larger percentage of these seedlings are resistant to blight than is found among the French seedlings. But it is not sufficiently resistant, and it is not as well adapted to shallow and wet soils as the French stock.

Search for blight-resistant pears. The writer realized that little progress could be made in the search for blight-resistant varieties until there was available in this country a complete collection of all known species of Pyrus, and many of the cultivated types of these various species. At the time this work was begun in 1912 there was no such collection in the United States. It is true that most of the better European varieties had been tested from time to time in this country and some collections are still in existence which include many of these varieties. None of the Experiment Stations, however, possessed more than three or four species of Pyrus, and none of them had a comprehensive collection of the Oriental varieties.

Pear collection at the Southern Oregon Experiment Station. During the past twelve years the Southern Oregon Experiment Station has assembled practically all the known species of Pyrus and numerous varieties of all the species from which cultivated types have been developed. This is probably the most comprehensive collection of pears in the world at this time. These species are natives of Europe, Northern Africa, Asia

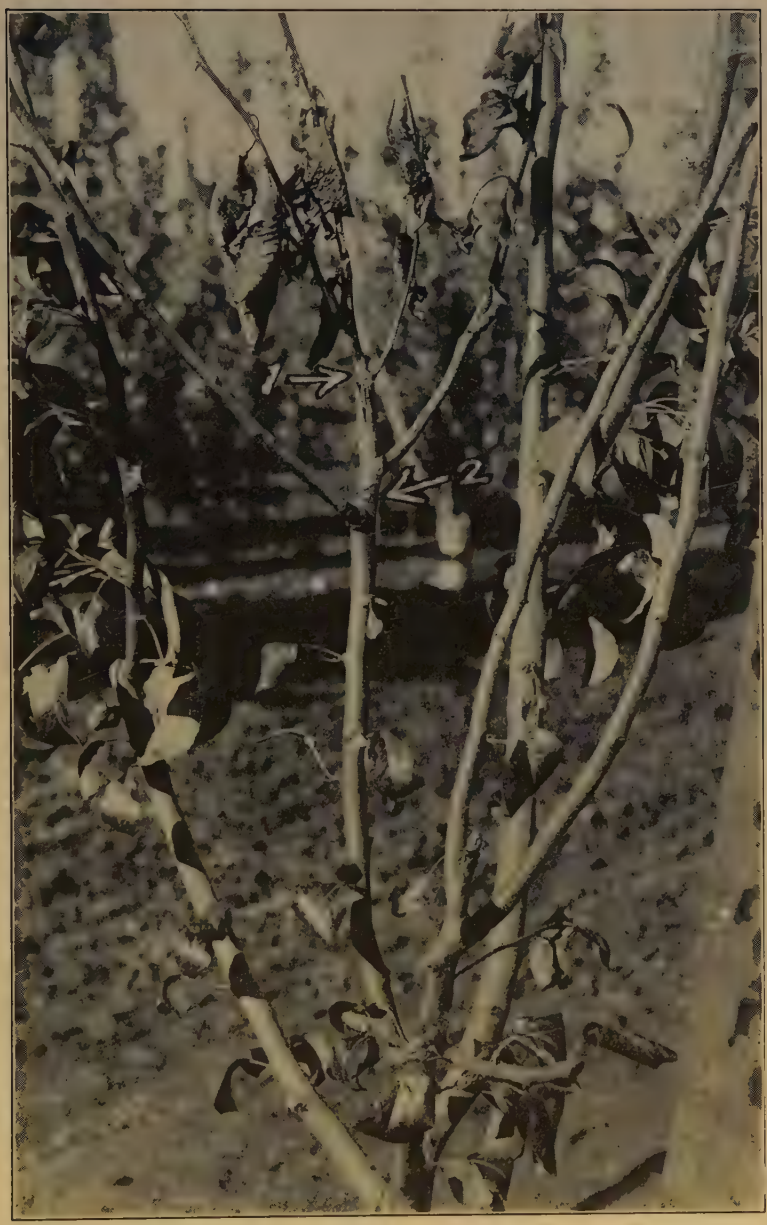

Fig. 3. Showing the Old Home pear tree top-worked with Bartlett at Arrow 1. The Bartlett scion became infected with blight and was killed. The disease extended into the Old Home stock to Arrow 2, a distance of only 2½ inches, where it stopped. This shows the high resistance of the Old Home to blight. If this had been a Bartlett trunk the disease would probably have extended down to the roots.

Minor, and Asia. They have been obtained from various sources, including arboretums, botanical gardens, the United States Department of Agriculture, private collections, explorers, missionaries, nurseries, foreign experiment stations, growers, and through extensive explorations by the writer in Japan, Korea, Manchuria, and China.

In making this collection it has been our aim to obtain and grow as many trees as possible of each of the most promising species. This in order to have available many trees of each for inoculation purposes and for a study of variations in vigor, resistance to blight, and habit of growth.

The writer was fortunate enough to obtain large quantities of seed of the various Oriental types, many of which have proved very valuable. Unfortunately, he has been able to obtain only one type of each of a number of the European and African species. Since all of these have proved very susceptible to Pear Blight, have produced no cultivated varieties, and possess other undesirable tree characteristics, it has not been deemed advisable to make extensive explorations for additional types of these species.

Testing for blight resistance. Since Pear Blight is an American disease and unknown in Europe, Asia, and Africa, no evidence could be obtained regarding the resistance or susceptibility of these various species in their native countries. It was therefore necessary to bring them to this country and make many inoculation tests. This work has been conducted at the Southern Oregon Experiment Station on an extensive scale every season during the past ten years. Many of these species have been under test and observation during the entire ten years, a few for the past eight years, and some of the Oriental varieties for a period of only five years. Since the work has been of such magnitude and has extended over such a long period we believe that the results obtained are representative of most of these types.

For several reasons the conditions in the Rogue River Valley are favorable for this work. Pear Blight is extremely virulent here. This is evidenced by the fact that the disease has been found in the orchards of the Valley every year since 1906, and has caused considerable loss each season where it was not properly combated. Under our soil and climatic conditions this disease attacks and destroys all portions of the tree, including blossoms, twigs, branches, trunk, and root system. Trunk and root blight is apparently more prevalent here than in the eastern states, and the disease is more active during the winter months in our mild climate than it is in the colder regions.

The soil conditions under which these trees have been grown are very conducive to the development of Pear Blight. The soil is commonly known as river bottom land and in a soil survey is classed as silty clay loam; it is very fertile and produces vigorous tree growth. For our inoculation tests we have used young trees which have been thoroughly cultivated and fertilized, heavily irrigated and severely pruned, and given all conditions which are conducive to the development of this disease.

Methods of inoculation. Fortunately, from the standpoint of testing for blight resistance, pear trees can be easily and readily inoculated on a large scale with the Pear Blight organism. Pure cultures of the disease can be readily obtained, and since the organism multiplies so

rapidly and thrives so well in the usual laboratory culture media, large quantities of the culture can be very easily and quickly prepared for inoculating purposes. Furthermore, the disease develops very rapidly, usually within three days after the inoculation is made, hence evidence on resistance or susceptibility can be very quickly obtained. All types in our collection which have shown a high degree of resistance to this disease have been repeatedly inoculated and the tests made as severe as possible.

Pure cultures have been used in practically every case with all of the types covered by these tests. In addition, some of the highly resistant types have been inoculated with quantities of fresh ooze taken from vigorously blighting trees. These ooze cultures, however, did not prove any better than the pure cultures.

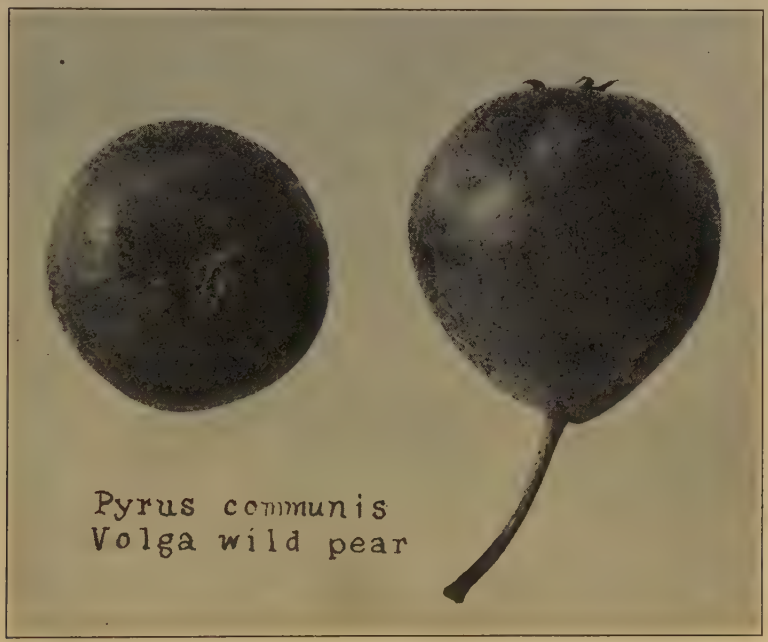

Fig. 4. Fruit of wild French pear *(P. communis)*. This is the fruit of the French seedlings which have been more largely used as stocks for American pear trees than any other species. It is far more susceptible to root blight than any of the other important species.

The usual method of inoculating is to place a drop of the culture on that portion of the tree to be inoculated and then pass a needle through this drop and deep into the bark, from five to ten times. The number of inoculations on all of the varieties and types showing resistance was very large, in some species amounting to thousands during the entire period covered by the test. Every blight culture used was tested by inoculating some susceptible variety like Bartlett, Bosc, or Howell, on the same day and in the same manner as the other varieties or species under test. Whenever these susceptible check trees did not blight readily the culture and results were discarded.

BLIGHT RESISTANCE IN SPECIES OF PYRUS

The inoculation results obtained with the wild type of the various species of Pyrus are given in Table I. This table gives the name and origin of the species, number of years inoculated, number of dates on which inoculated, age of trees during the inoculation period, number of trees inoculated, and number of tip and trunk inoculations; percent of tip and of trunk infections, and a classification of the latter showing the percent of light, medium, and heavy infections.

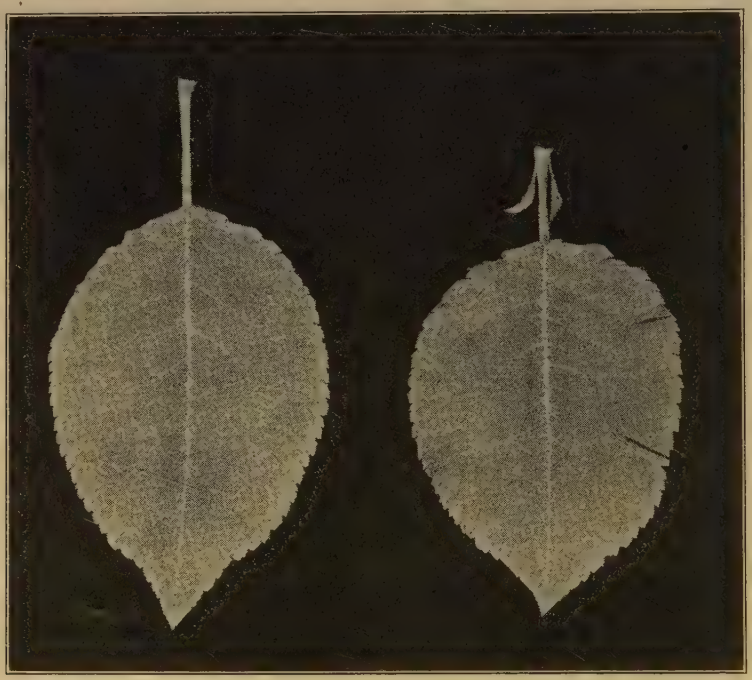

Fig. 5. Typical leaves of a French seedling *(P. communis).*

While at least several trees were inoculated in every species, only one type or variety was available for inoculation in each of the following species: *P. amygdaliformis, P. balansae, P. bretschneideri, P. canescens, P. cordata, P. cotinifolia, P. elaeagrifolia, P. fascicularis, P. glabra, P. heterophylla, P. longipes, P. malifolia, P. mamorensis, P. michauxii, P. nivalis, P. ovoidea, P. parviflora, P. persica, P. salicifolia,* and *P. sinaica.* The several trees belonging to each of these species used in the inoculation work were propagated from one original tree by grafting. It is unfortunate that only one type of each was available, as some of the other types belonging to these species might have shown greater resistance than those used. Since all of these, however, with the exception of *P. ovoidea,* proved highly susceptible, they do not appear very promising.

TABLE I. INOCULATION RESULTS FROM ALL SPECIES OF PYRUS
(Cultivated varieties not included.)

SPECIES	Age of trees.	Number of years inoculated.	Tip inoculations: Number dates on which inoculated.	Tip inoculations: Total number trees inoculated in tips.	Tip inoculations: Total number of tip inoculations	Tip inoculations: Percent of trees infected in tips.	Trunk inoculations: Number dates on which inoculated.	Trunk inoculations: Total number trees inoculated on trunks.	Trunk inoculations: Total number trunk inoculations.	Trunk inoculations: Percent of trees infected in trunks.	Trunk inoculations: Percent of trees with light trunk infection.	Trunk inoculations: Percent of trees with medium trunk infection.	Trunk inoculations: Percent of trees with heavy trunk infection.
						%				%	%	%	%
P. amygdaliformis, Vill.	2-6	7	3	7	25	100.0	11	18	76	83.3	5.5	.0	77.8
P. balansae, Decne.	1-6	7	4	10	20	100.0	12	18	67	100.0	16.6	5.6	77.8
P. betulaefolia, Bunge.	2-7	10	15	514	4217	96.5	15	850	4046	93.1	8.0	14.5	70.6
P. bretschneideri, Rehd.	1-4	7	3	4	24	100.0	14	24	111	50.0	37.5	4.2	8.3
P. calleryana, Decne.	1-7	9	19	564	9125	94.5	18	564	5492	29.6	12.1	6.5	11.0
P. calleryana-dimorphophylla, Koidz.	4-5	2	3	37	155	97.3	2	36	152	63.9	8.3	2.8	52.8
P. canescens, Spach.	2-6	6	3	3	15	100.0	9	10	30	80.0	.0	.0	80.0
P. communis, Linn. (French seedlings)	1-7	10	13	220	1117	100.0	20	247	841	93.8	9.2	10.5	74.1
P. cordata, Dasv.	2-6	7	3	7	15	100.0	14	17	57	100.0	.0	.0	100.0
P. cotinifolia, Hort.	2-8	8	5	9	25	100.0	17	26	100	65.3	3.8	.0	61.5
P. elaeagrifolia, Pall.	2-6	7	3	7	25	100.0	12	15	57	93.3	.0	.0	93.3
P. fascicularis, Hort.	2-6	7	4	6	24	100.0	14	22	66	77.3	18.2	.0	59.1
P. fauriei, Schneid.	2-4	1	1	14	42	100.0	1	14	42	42.8	.0	21.4	21.4
P. glabra, Boiss.	2-6	6	5	9	25	100.0	8	8	28	100.0	.0	12.5	87.5
P. heterophylla, Regel and Schmalh.	2-6	6	5	10	22	100.0	13	17	45	88.3	11.8	.0	76.5
P. hondoensis, Nakai and Kikuchi	2-4	4	4	10	6	90.0	4	4	20	75.0	.0	.0	75.0
P. koehnei, Schneid.	2-3	2	5	5	15	100.0	3	11	33	54.6	27.3	.0	27.3
P. longipes, Coos. and Dur.	2-6	7	3	3	13	100.0	9	11	37	100.0	.0	.0	100.0
P. malifolia, Spach.	2-5	7	4	7	18	100.0	14	20	78	90.0	20.0	5.0	65.0
P. mamorensis, Trabut.	1	1	1	1	3	100.0	1	1	3	100.0	.0	.0	100.0
P. michauxii, Bosc.	2-5	7	3	6	30	100.0	10	16	64	93.7	.0	.0	93.7
P. nivalis, Jacq.	2-5	7	3	7	13	100.0	9	11	37	100.0	.0	.0	100.0
P. ovoidea, Rehd.	2-8	7	9	20	122	100.0	19	42	200	21.5	16.7	.0	4.8
P. parviflora, Desf.	2-8	7	3	7	11	100.0	9	15	53	100.0	.0	.0	100.0
P. pashia, Buch.-Ham.	2-5	7	3	8	31	100.0	8	9	40	77.7	33.3	.0	44.4
P. persica, Pers.	1-5	5	3	5	13	100.0	5	5	19	100.0	.0	.0	100.0
P. phaeocarpa, Rehd.	2-7	7	10	12	44	100.0	19	22	87	95.4	.0	.0	95.4
P. salicifolia, Pall.	2-5	7	3	4	20	100.0	8	8	30	100.0	.0	.0	100.0
P. serotina, Rehd. (Japanese seedlings)	1-8	10	17	155	935	97.4	25	227	984	55.9	16.3	3.1	36.5
P. serrulata, Rehd.	2-7	6	8	177	867	97.7	9	177	2157	72.3	32.2	.0	40.1
P. sinaica, Dum.	2-6	7	4	4	25	100.0	14	17	63	100.0	.0	.0	100.0
P. ussuriensis, Maxim. (wild)	1-5	5	8	182	266	31.8	8	69	217	7.2	2.9	.0	4.3
P. ussuriensis, Maxim. (seedlings of cultivated varieties)	2-7	6	11	927	7770	94.5	11	1022	6433	52.2	8.1	8.0	36.1

Many types were used in the work with *P. betulaefolia, P. calleryana, P. communis, P. serotina, P. serrulata,* and *P. ussuriensis,* the number of seedlings corresponding with the number of trees used, as shown in Table I.

Fig. 6. Fruit and leaf of *P. calleryana.* (Natural size.)

It is evident from the number of dates on which inoculations were made in each species, that most of the trees were inoculated repeatedly. This was done to test their resistance and susceptibility at various seasons of the year, at different ages, and at various stages of growth.

Table I gives a summary of the results obtained from tip and trunk inoculations. Only the more promising species, and especially those of which seedlings were available, were also inoculated in the roots, and the results of this work are given in Table II.

Results from tip inoculations. It is evident from Table I that in not a single species did all the individuals prove immune. The results also show that in the following twenty-five species not one immune individual was found: *P. amygdaliformis, P. balansae, P. bretschneideri, P. canescens, P. communis, P. cordata, P. cotinifolia, P. elaeagrifolia, P. fascicularis, P. fauriei, P. glabra, P. heterophylla, P. koehnei, P. longipes, P. malifolia, P. mamorensis, P. michauxii, P. nivalis, P. ovoidea, P. parviflora, P. pashia, P. persica, P. phaeocarpa, P. salicifolia,* and *P. sinaica.* It is probable that immune individuals would have been found in some of these highly susceptible species if a much larger number of seedlings or types had been available for the inoculation work. In all of our work, only seven species have produced individuals which proved immune in the tender tips, and with one exception the number of such immune trees is extremely small in every species. The wild type of *P. ussuriensis* stands at the head of this list with one hundred and twenty-four trees, or 68.2 percent immune. *P. hondoensis* produced one tree, or 10 percent immune. This probably is not representative of the species, owing to the small number of trees tested. For good reasons which will be discussed later, the seedlings of the cultivated varieties of *P. ussuriensis* have been placed in a second group. This group of varieties gave an average of 5.5 percent immune trees. *P. calleryana* gave identical results, with thirty-one seedlings, or 5.5 percent immune. *P. betulaefolia* follows with eighteen trees, or 3.5 percent immune. In degree of resistance there is very little difference between the remaining three species. *P. calleryana-dimorphophylla* produced one immune individual out of thirty-seven, or 2.7 percent. *P. serotina,* which includes the type commonly known among nurserymen as Japanese seedlings, rewarded us with four immune trees, or 2.6 percent. The hybrid group known as *P. serrulata* gave 2.3 percent, or four immune trees.

All the immune trees belong to the Chinese and Japanese species. Not one has appeared among the European, African, or Indian species.

In recording the results, all infections, no matter how slight, have been classed with the susceptible trees. In some species, many of the infections have been very slight, killing the tips for a distance of only one to six inches. This was particularly true with many of the infections in *P. calleryana* and *P. ussuriensis.* Even in the most resistant species, however, the infections in many of the seedlings were severe, killing the shoots and branches to the trunk.

Owing to the great variation in severity of infection on different trees and at various seasons, within the same species, the extent of tip infection has not been given in Table I.

The fact should be borne in mind that the tips of the young tender shoots are usually more readily infected than any other part of the tree. Most of the trees in certain species could be readily infected in the tips, but in many of these it was impossible to produce a single infection in the older and harder wood. This will be evident when the trunk inoculations are considered.

The largest number of trees has been tested and the greatest number of inoculations made in the following species: *P. betulaefolia, P. calleryana, P. communis, P. serotina, P. serrulata,* and *P. ussuriensis.* These include the two species now most extensively used and also all those showing the greatest promise for stock purposes and for breeding work.

With several species the work has been too limited to be conclusive. These appear to be of little value, however, owing to their small size, lack of vigor, and apparent susceptibility to blight.

Fig. 7. Splendid tree of *P. calleryana,* on river bank, southern Shantung Province, China.

In the types in which 100 percent of the trees have proved susceptible, most of the inoculations were successful. In some of these species, notably *P. ovoidea,* it was often necessary to inoculate trees a second time to infect them.

In the most resistant species it is necessary to repeat the inoculations many times during at least two seasons, and at various stages of growth, before a seedling can be pronounced immune. We have found this to be true particularly of *P. calleryana* and *P. ussuriensis.* The apparently immune

trees belonging to these and other resistant species have been given the severest tests possible; they have been inoculated repeatedly at various ages, at different stages of growth, and under the most favorable growing conditions. With such treatment some of them resisted all inoculations during the first season and blighted readily during the following year. In a number of cases they resisted all attempts for two seasons and then blighted during the third year. One tree of *P. calleryana* failed to blight when inoculated repeatedly each season for four consecutive years and then became naturally infected in several of the blossoms during the fifth summer. In this tree, however, as in nearly all of those which had resisted the disease for two seasons, the infections were limited to the fruit spurs and the young tender growth of the current season.

From these results it is apparent that the degree of resistance varies, in a measure, with age and seasonal conditions. It is necessary to inoculate a tree repeatedly for several seasons and at various stages of growth before it can be pronounced immune. For this reason, most of the trees which have been recorded as immune in Table I are those which have been very severely tested for several seasons and which have, so far, resisted all inoculations. Additional results emphasizing the effect of varying seasonal conditions on resistance will be presented later in connection with the results obtained with a number of resistant cultivated varieties.

The fact should also be emphasized that not every lot of trees belonging to a certain species will give the same percentage of immune and susceptible trees that we have recorded in Table I. This table is simply a summary of all the results obtained during several seasons. The results obtained with different lots of trees of a certain species often vary greatly. For example, in one lot of twenty-two trees of wild *P. ussuriensis* all proved immune, while in another lot of fifty trees only 46 percent were immune. This is due to the great variation in seedlings, whether judged from the standpoint of disease resistance or other characteristics.

The results from tip inoculations presented in Table I show clearly that the vast majority of trees, in all but one species, blight readily in the tender tips. These results do not necessarily indicate the true value of these species, especially for stock purposes. Undoubtedly the results obtained from trunk and root inoculations are the best index of the value of a species.

Results from trunk inoculations. Table I also gives the results obtained from trunk inoculations. Record has been made of the number of trees used in each species, the number of inoculations made, and the percentage of trees infected. The table gives the total percentage of trees infected and also the degree of infection, which is recorded as light, medium, and heavy. All trees in which less than one-third of the trunk blighted have been classified as "light;" those in which from one-third to two-thirds of the trunk blighted have been classified as "medium;" and those in which more than two-thirds of the trunk blighted have been classified as "heavy."

Ten species proved highly susceptible, with a total of 100 percent infection. In eight of these; namely, *P. cordata, P. longipes, P. mamorensis, P. nivalis, P. parviflora, P. persica, P. salicifolia* and *P. sinaica,* all infections were classed as heavy, while in *P. balansae* 77.8 percent and in *P. glabra* 87.5 percent were heavy infections.

The following group of six species ranks next with a total of between 90 and 100 percent trunk infections: *P. betulaefolia, P. communis, P. elaeagrifolia, P. malifolia, P. michauxii* and *P. phaeocarpa.* These also gave a

Fig. 8. Showing characteristic trunk of large tree of *P. calleryana.* Compare this with trunk of *P. betulaefolia* and that of *P. ussuriensis.*

high percentage of heavy trunk infection, ranging from 65 percent in *P. malifolia* to 95.4 percent in *P. phaeocarpa.*

A third group of six species gave a total of between 75 and 90 percent of trunk infections. This group includes *P. amygdaliformis, P. canescens, P. fascicularis, P. heterophylla, P. hondoensis* and *P. pashia.*

In the following group of six species from 50 to 75 percent of the inoculated trunks blighted: *P. bretschneideri,* seedlings of cultivated varieties of *P. ussuriensis, P. calleryana-dimorphophylla, P. cotinifolia, P. koehnei,* and *P. serrulata.* In this group *P. bretschneideri* and cultivated *P. ussuriensis* proved most resistant and *P. cotinifolia* and *P. serrulata* most susceptible.

Only four species gave a total of less than 50 percent infection in the trunks. Of these the wild type of *P. ussuriensis* was most resistant, with a total infection of 7.2 percent, and only 4.3 percent heavy infections. *P. ovoidea* ranks second with a total of 21.5 percent and 4.8 heavy infections. *P. calleryana* produced a total of 29.6 percent infections of which 11 percent were heavy. *P. fauriei* gave a total of 42.8 percent infections, half of which were classed as medium and half as heavy. It is possible that the number of *P. fauriei* trees inoculated was too small to give conclusive results. Since this species is a very dwarf grower and produces worthless fruit it was not considered advisable to extend the work with this type.

It is interesting to note the fact that these four most resistant species are all of Oriental origin: *P. ussuriensis, P. ovoidea,* and *P. calleryana* come from China, and *P. fauriei* from Korea. Furthermore, of the seven species which, as a group, ranked second highest in resistance with a total of from 50 to 75 percent infection, six are also of Oriental origin: *P. bretschneideri, P. koehnei,* and *P. serrulata* are natives of China, *P. calleryana-dimorphophylla* and *P. hondoensis* of Japan, and *P. serotina* of both China and Japan. Of the other twenty-two species, all of which gave more than 75 percent trunk infection, seventeen are natives of Europe, two of Africa, one of India, and two of China.

One would expect all of the trees belonging to a species and propagated asexually (by grafting) from one tree, to give similar results when inoculated; that is, if part of the trees are killed one would expect all of them to be killed. This has not been the case, as the degree of trunk infection in many of these species has varied considerably. This variation in resistance is due to differences within the same variety at different stages of growth and particularly at different seasons of the year. A certain tree may be very susceptible during the period of flush growth in spring and early summer, but moderately resistant during the season of slow growth after mid-summer.

Our results also show that it is much harder to infect the trunks than the tender tips of most of the species; in all but eight species the percentage of trunk infection is less than that of the tip infection. As will appear later, the reverse is true in a few varieties.

BLIGHT RESISTANCE IN THE FIVE MOST IMPORTANT SPECIES OF PEARS

For the convenience of the reader and to facilitate a further comparative study, the results obtained from the five most important species are presented in Table II. The results obtained from the tip and trunk inoculations of these species have already been presented in Table I. In addition, Table II

TABLE II. INOCULATION RESULTS FROM SEEDLINGS OF MOST IMPORTANT SPECIES OF PYRUS

SPECIES AND VARIETIES	Tip inoculations						Trunk inoculations								Root inoculations			
	Age of trees.	Number of years inoculated.	Number of dates on which inoculated.	Total number of trees inoculated in tips.	Total number of tip inoculations.	Percent of trees infected in tips.	Number of dates on which inoculated.	Total number of trees inoculated on trunks.	Total number of trunk inoculations.	Percent of trees infected on trunks.	Percent of trees with light trunk infection.	Percent of trees with medium trunk infection.	Percent of trees with heavy trunk infection.	Percent inoculated trunks blighted into roots.	Number of dates on which inoculated.	Total number of trees inoculated in roots.	Total number of root inoculations.	Percent of trees infected in roots.
						%				%	%	%	%	%				%
P. betulaefolia	2-7	10	15	514	4217	96.5	15	850	4046	93.1	8.0	14.5	70.6	14.6	6	66	166	24.2
P. calleryana	1-7	9	19	564	9125	94.5	18	564	5492	29.6	12.1	6.5	11.0	2.5	5	175	529	9.1
P. communis (French seedlings)	1-7	10	13	220	1117	100.0	20	247	841	93.8	9.2	10.5	74.1	39.2	10	98	295	43.8
P. serotina (Japanese seedlings)	1-8	10	17	155	935	97.4	25	227	984	55.9	16.3	3.1	36.5	11.8	6	136	291	23.5
P. ussuriensis—summary. Seedlings of all cultivated varieties*	2-7	6	11	927	7770	94.5	11	1022	6433	52.2	8.1	8.0	36.1	7.6	6	180	825	12.0
P. ussuriensis. Seedlings of individual cultivated varieties—																		
Ba Li Hsiang	2-5	4	8	215	2147	67.9	6	216	1671	19.9	6.9	4.2	8.8	.0	5	103	654	3.9
An Li	2-5	4	4	33	270	100.0	5	84	348	71.4	7.1	4.8	59.5	8.3	-----	-----	-----	-----
Chieh Li	2-5	4	7	139	1140	93.5	6	125	890	76.8	7.2	10.4	59.2	10.4	-----	-----	-----	-----
Chien Pa	2-5	4	5	95	714	92.6	6	76	586	67.1	7.9	11.8	47.4	14.5	-----	-----	-----	-----
Chiu Suan	3-5	3	5	45	276	100.0	5	30	240	50.0	10.0	16.7	23.3	3.3	-----	-----	-----	-----
Chiu Tze	2-5	4	5	85	645	100.0	6	111	575	50.4	6.3	9.9	34.2	14.4	-----	-----	-----	-----
Guar Li	3-7	6	8	18	151	94.4	7	16	172	37.5	.0	.0	37.5	6.2	-----	-----	-----	-----
Hua Kai	3-5	3	5	72	447	100.0	5	72	328	63.8	11.1	12.5	40.2	19.4	1	47	141	25.5
Hung Guar	2-7	5	11	57	555	98.3	11	57	505	65.0	15.8	1.8	47.4	1.8	-----	-----	-----	-----
Hu Pi Hsiang	3-5	3	5	63	324	100.0	5	42	300	57.1	11.9	14.3	30.9	2.4	-----	-----	-----	-----
Man Yuan Hsiang	2-5	3	7	66	517	92.4	5	134	263	29.0	.7	1.5	26.8	5.2	1	30	30	6.7
Ta Tze Hsiang	4-7	5	6	10	212	90.0	7	30	249	50.1	6.7	6.7	36.7	3.3	-----	-----	-----	-----
Tzu Ma Li	4-5	2	4	29	372	100.0	4	29	306	41.3	13.8	10.3	17.2	10.3	-----	-----	-----	-----

*The percentages of tip, trunk, and root infections shown are the averages of the varieties tested.

gives the root infections resulting from trunk and root inoculations of these species, and also the results obtained from the inoculations of the seedlings of each of the cultivated varieties of *P. ussuriensis*.

Since some of these species have proved highly susceptible the reader will naturally want to know why they have been included in this list of most important species. They are classed with this group because some of them have shown a high degree of resistance to blight, and others possess certain

Fig. 9. Showing *P. calleryana* tree growing at the edge of a pond, central China. Part of the trunk immersed in water.

characteristics which make them valuable from a commercial standpoint. In addition, three of them: namely, *P. communis, P. serotina,* and *P. ussuriensis,* are the parents of the leading commercial varieties in America and the Orient.

A thorough discussion of the characteristics of each of these species appears in the second part of this bulletin, in which their importance will become apparent.

On the other hand, some of the species which possess a high degree of resistance have not been included because of certain undesirable traits. While the wild type of *P. ussuriensis* has shown a greater degree of resist-

ance than any other species, it cannot be considered important, because its extremely slow growth makes it worthless for stock purposes and its fruit is of too poor quality to be of any value. *P. calleryana-dimorphophylla, P. hondoensis,* and *P. serrulata,* all of which produced some trees that proved immune in the tips, have not been included in the list of most important species because they proved very susceptible in the trunks and manifested certain undesirable growth characteristics. *P. fauriei,* while showing a good degree of resistance in the trunks, has not been included owing to the fact that it is a dwarf and the fruit is worthless. *P. ovoidea* has been eliminated, as only one type has been tested; this is apparently a hybrid and its seedlings are extremely variable.

Results from tip inoculations. A summary of the results obtained from the tip inoculations in these species appeared in Table I, and since these results have already been discussed, little further comment regarding most of them is necessary. While in all of these species 90 percent or more of the trees have blighted, it is highly important to remember that four of them—*P. betulaefolia, P. calleryana, P. serotina,* and *P. ussuriensis*—have produced some immune individuals. These trees have proved immune in the trunks and roots as well as in the tips. So far as the writer is aware, these are the first immune pear seedlings that have been found in America among those thoroughly tested by inoculation. While immune pear trees are evidently very rare, it is highly significant to establish the fact that such trees do exist. The writer believes that in the future these immune trees will play a very important part in the pear industry of this country.

Since *P. communis* includes the French seedlings which have always constituted the chief rootstock for pears in this country, special attention should be directed to the results obtained with this species. While not one of the seedlings proved immune, six have shown a high degree of resistance. In three of these most of the inoculations failed. The successful infections have been confined to the tips of the tender current season's growth, in the most severe cases killing these shoots from ten to twenty inches, to a diameter of .2 to .3 inch. In the other three trees the most severe infections have been confined to the current season's growth and to the upper four to six inches of the previous year's wood. All the trunk and root inoculations in these failed. They have been repeatedly inoculated and all the check trees under the same conditions were readily killed by the disease. It is probable that these trees would remain entirely free from the disease when grown under normal conditions and left to natural infection. The propagation work now in progress with them will be discussed later in this bulletin in the section on rootstocks.

The average percentage of infection for the seedlings of the several varieties of *P. ussuriensis* is 94.5 percent. While the seedlings of only thirteen varieties of *P. ussuriensis* were tested, these are the leading varieties in China, hence the results are probably representative of this species. Such marked variation occurred among the seedlings tested that it is deemed necessary to present the results from each of these varieties in the second part of Table II. From these results it is apparent that there is a greater difference among the varieties of this group than there is between the average of this group and any of the other four species. The percentage of trees infected in the different varieties ranges from 67.9 percent in the most resistant to 100 percent in the most susceptible. In six of the varieties 100 percent of the trees blighted. In six other varieties from 90 to 98.3 percent of the

trees blighted. One variety, Ba Li Hsiang, is in a class by itself so far as resistance is concerned, since only 67.9 percent of the trees were infected.

In *P. calleryana* 94.5 percent of the trees blighted in the tips. This species and the cultivated varieties of *P. ussuriensis,* therefore, gave identical

Fig. 10. Tree of *P. calleryana* growing on a dry, rocky mountainside in Shantung Province, China.

results and have proved more resistant in the tips than any of the others in this group of most important species.

P. betulaefolia ranks third in resistance with 96.5 percent of the trees infected. It is indeed fortunate that some of the trees of this species have

proved immune, since at this Station it propagates more readily from root cuttings than any other species tested. These immune trees may therefore prove of great value as blight-resistant stocks.

In the *P. serotina* group, including the Japanese Sand pears, 97.4 percent of the trees blighted. While this species proved slightly more susceptible in the tips than *P. betulaefolia,* it proved far more resistant in the trunks than that species.

Results from trunk inoculations. Of all those species having economic value *P. calleryana* has shown the greatest resistance in the trunks. In this species the total percent of trunks infected is 29.6 percent. Only 11 percent of the inoculated trees show heavy infection. This should be compared with the seedlings of the cultivated types of *P. ussuriensis,* which rank second in resistance and in which 52.2 percent of the trunks blighted and 36.1 percent of them ranked as heavy infections. The degree of infection varies tremendously among the several varieties within this group, and for this reason the inoculation results obtained from the individual varieties are given in the second part of Table II. The percentage of infected trees varies from 19.9 percent in Ba Li Hsiang, which is the most resistant, to 76.8 percent in Chieh Li, which proved the most susceptible. There is therefore a greater difference between the most resistant and the most susceptible variety of this group than there is between this group as a whole and any of the other species. Of the thirteen varieties tested, only four: viz., Ba Li Hsiang, Guar Li, Man Yuan Hsiang, and Tzu Ma Li, showed less than 50 percent infection. *P. serotina* ranks third in resistance, with 55.9 percent of the trunks infected. In the total percentage of trunks infected there is very little difference between *P. betulaefolia* and *P. communis,* the former showing 93.1 percent and the latter 93.8 percent.

It is important to note the percentage of trunk infections rated as heavy in each of these species and varieties. In this respect it is evident that the species again rank as they did for total percentage of trunk infections, although the difference between some of the species is even more marked. It is apparent that *P. calleryana* again stands at the head of the list in resistance, with only 11 percent of the trees showing heavy trunk infection. *P. ussuriensis* ranks second with 36.1 percent, more than three times as many of the trees showing heavy infection as in *P. calleryana. P. serotina* ranks next with 36.5 percent heavy infection. *P. betulaefolia* and *P. communis* gave a very high percentage of heavy infection, with 70.6 and 74.1 percent respectively.

The seedlings of the different varieties of *P. ussuriensis* show great variation in the percentage of heavy infections. Ba Li Hsiang again ranks first in resistance, with 8.8 percent infection. This one variety of *P. ussuriensis* has therefore proved even more resistant than *P. calleryana.* Three other varieties; namely, Chiu Suan, Man Yuan Hsiang, and Tzu Ma Li, gave less than 30 percent heavy infections. In four varieties, Chiu Tze, Guar Li, Hu Pi Hsiang, and Ta Tze Hsiang—from 30 to 40 percent of the trees showed heavy infection. Three varieties, Chien Pa, Hua Kai, and Hung Guar, produced 40 to 50 percent of trees with heavy infection. An Li and Chieh Li proved most susceptible, with 59.5 and 59.2 percent infection respectively. It is interesting to note that all of the varieties of *P. ussuriensis,* with the exception of Ba Li Hsiang, produced a much larger percentage of trees with heavy trunk infection than did *P. calleryana.*

Root infection resulting from trunk inoculations. Perhaps the most important results obtained from trunk inoculations are those showing the percentage of trees in which the disease extended from the trunks into the roots. These data are especially valuable since it has become very evident that seedlings should never be used in propagation work for any portion of the tree except the rootstock.

In Table II the last column under trunk inoculations gives the percentage of root infection resulting from trunk inoculations. It is quite apparent from these results that only a comparatively small percentage of the trunk

Fig. 11. Fruit of wild *P. ussuriensis.* (Natural size.)

infections extended into the roots, except in *P. communis. P. calleryana* again stands at the head of the list, with only 2.5 percent of the trunk infections extending into the roots. This is approximately one-third as many as in *P. ussuriensis,* which is the next most resistant species, with 7.6 percent. *P. serotina* ranks third in resistance with 11.8 percent of the roots infected. The results from *P. betulaefolia* are interesting since only 14.6 percent of the trees blighted in the roots, while 70.6 percent blighted in the trunks. The French seedlings, listed as *P. communis,* proved the worst blighters, the disease extending into the roots of 39.2 percent of the trees inoculated in the

trunks. One of the outstanding results in all of our work has been the very much higher proportion of trunk infection extending into the roots of *P. communis* than in the other four species, which are all of Oriental origin. In the vast majority of heavily infected trees, in these Oriental species, the disease progresses through the trunk with great rapidity, but stops at or just above the surface of the ground. At this point the trees evidently possess a much greater degree of resistance than in the higher portions.

The several varieties of *P. ussuriensis* again show marked differences in resistance. Ba Li Hsiang stands at the head of the list with no infection. The four varieties, Chiu Suan, Hung Guar, Hu Pi Hsiang, and Ta Tze Hsiang, rank next in resistance, each with less than 4 percent infection. Three varieties, An Li, Guar Li, and Man Yuan Hsiang, show from 5 to 8.3 percent infection. The five varieties showing the greatest susceptibility are Chieh Li, Chien Pa, Chiu Tze, Hua Kai, and Tzu Ma Li, with from 10 to 19.4 percent of the trees infected in the roots.

The seedlings of only three varieties of *P. ussuriensis,* Ba Li Hsiang, Hung Guar, and Hu Pi Hsiang, showed a smaller percentage of root infection resulting from trunk inoculations than did *P. calleryana.*

Results from root inoculations. The last part of Table II gives the results from the inoculations made directly into the roots. A glance shows that *P. calleryana* again proved the most resistant of these species, with only 9.1 percent of the inoculated trees infected. It is very gratifying that this species should prove to be the most resistant in the roots as well as the trunks. *P. ussuriensis* ranks second in resistance, with 12 percent as the average for the varieties tested. This result is not conclusive, since it is based on work with only three varieties of this group. When judged by the percentage of root blight resulting from trunk inoculations, it is evident that two of these varieties, Ba Li Hsiang and Man Yuan Hsiang, rank among the most resistant, and the other variety, Hua Kai, is one of the most susceptible. There certainly is great variation in the degree of susceptibility of these three varieties of *P. ussuriensis,* ranging from slightly less than 4 percent infection in Ba Li Hsiang, to more than 25 percent in Hua Kai. Two of these varieties, Ba Li Hsiang and Man Yuan Hsiang, proved more resistant in the roots than *P. calleryana,* and the other variety, Hua Kai, far more susceptible. It is of great interest and importance to note the low percentage of root infections resulting from trunk and root inoculations in the seedlings of Ba Li Hsiang. Ba Li Hsiang is one of the few varieties which have proved absolutely immune in all of our inoculation work. This variety evidently is able to transmit this characteristic to its seedlings in a much greater degree than any of the others tested.

It is unfortunate that the other ten varieties of *P. ussuriensis* were not inoculated in the roots. It is evident, however, from the root infections resulting from the trunk inoculations of these varieties that Chiu Suan, Guar Li, Hung Guar, Hu Pi Hsiang, and Ta Tze Hsiang are quite resistant to root blight, while An Li, Chieh Li, Chien Pa, Chiu Tze, and Tzu Ma Li are susceptible. It is certain that the seedlings of those varieties which gave a high percentage of root infection as a result of trunk inoculation should not be used as stocks. In fact, the satisfactory results obtained from Ba Li Hsiang indicate that this variety should be given preference over all other varieties of this species so far tested.

The root inoculations in *P. serotina* and *P. betulæfolia* gave similar results, both species showing a high degree of infection, the former with 23.5 percent and the latter with 24.2 percent of the trees blighted. While this percentage of infection is practically twice as high as the average for the

Fig. 12. Leaf of wild type of *P. ussuriensis.*

three *P. ussuriensis* varieties, it is still slightly less than that of Hua Kai, which is the most susceptible variety of *P. ussuriensis* tested.

The *P. communis,* or French seedlings, again proved far more susceptible than those of any other species, with 43.8 percent of the roots infected. This percentage is nearly five times as great as in the case of *P. calleryana. P.*

communis has been consistent in its blighting propensities, since it has proved the most susceptible of all the species tested in the tips, trunks, and roots. These inoculation results are also in harmony with the behavior of this species when used as a rootstock in commercial orchards where heavy losses from root blight are often experienced.

The reader must be cautioned not to expect identical results from every lot of seedlings of these particular species and varieties. Unquestionably the results will vary with every lot of seedlings grown from seed collected from different trees of the same species. The results presented show conclusively that there is great variation among the seedlings of each species. The parent seed trees from which the seeds are collected differ similarly. It is highly probable that some of the resistant mother seed trees will give a much higher percentage of resistant seedlings than the average for the species. The preliminary results obtained at this Station indicate that this is the case, at least in *P. ussuriensis*. Seeds from the immune Ba Li Hsiang produce a higher percentage of immune seedlings than those from any other variety. Work is now in progress at this Station to isolate, in each of the most desirable species, resistant mother trees which will have this characteristic of transmitting to their seedlings a high degree of resistance to blight. The writer believes that eventually such trees will be found.

It is equally important to find desirable resistant male trees to serve as pollinators for the mother trees. It is well known that the majority of our varieties and seedlings of pears are self-sterile, and must be supplied with pollen from another variety to produce seed. It is also well known that the male parent is just as potent as the mother tree in transmitting to seedlings the characteristic of resistance or susceptibility. To discover such trees it will be necessary to hand-pollinate the blossoms of the desirable mother trees with pollen from the various promising pollen-bearing trees, and later test for resistance the seedlings of each combination. When such desirable trees are found seed orchards must be planted in isolated places to prevent pollination with undesirable varieties. Until this is done we will never have dependable supplies of seed for stock purposes. The present method of collecting seed indiscriminately from any available tree, or as is more often done, from the pomace at cider mills, is responsible for the high percentage of unsatisfactory trees.

Pear stocks from root cuttings. The results presented have repeatedly brought out the fact that there is marked variation in the seedlings of every species of Pyrus, ranging from trees which are highly resistant to those which are very susceptible to blight. Although some species have given a much higher percentage of resistant seedlings than others, the extremes among the seedlings of one species are just as great as those of any other. Each species also shows a wide variation in vigor among the seedlings, some trees being slow growers, while others are extremely vigorous. The root systems vary from types having a long, single, unbranched tap-root to those with a highly desirable well branched system.

The most desirable pear stock is one with all the individuals uniform, resistant to blight, mushroom root rot, crown gall, and woolly aphis; one that is vigorous, hardy, well branched and makes a strong and congenial union with the variety upon it; that will thrive on a diversity of soils, including soils that are shallow and wet as well as those that are deep and well drained, and one that has a long budding season.

Fig. 13. Leaf of Chieh Li, a cultivated variety of *P. ussuriensis.*

Owing to the variation in seedlings it is likely that it will never be possible to produce seedlings all of which will be uniform and also meet all the requirements of the ideal stock above described.

It now seems probable that the most certain method of obtaining uniform and desirable rootstocks will be from root cuttings. Cuttings made from the roots of a seedling will reproduce that seedling true to type, and it has been demonstrated by this Experiment Station and by the United States Department of Agriculture[8] that seedling pear trees can be reproduced in this manner. Experiments are now in progress to determine the most economical and rapid method of producing stocks from root cuttings on an extensive commercial scale. It has already been determined that some seedlings will propagate more readily than others of the same species. Furthermore, certain species propagate more readily from root cuttings than others. *P. betulaefolia* apparently propagates readily in this manner and in our preliminary work it has given us a better stand of plants than any other species. By this method, however, we have obtained some plants from *P. calleryana, P. communis,* and *P. ussuriensis.*

Among the seedlings of each of the five most important species we have found some which are far superior to others in vigor, resistance to disease, and type of root system. Work is now in progress to propagate these seedlings from root cuttings. In all of the species special attention should be given to the selection of individuals that are vigorous, immune to blight, and possess a well branched root system.

When this method of propagation is adopted it is best to use roots one-fourth to one-half inch in diameter. These are cut into lengths of three to four inches and planted in an upright position, with the upper end of the cutting approximately one-half inch below the surface of the ground. In Southern Oregon the best time to make and plant these cuttings is in the late fall and early winter months.

Certain types of *P. calleryana* have been successfully propagated from branch cuttings in northern Florida, and these trees when transplanted to Oregon have proved very vigorous. This method of propagation has not proved successful in Oregon. Furthermore, it has not been demonstrated that rootstocks grown from branch cuttings will prove as satisfactory and long lived as those propagated from roots. Until this is demonstrated the root cuttings should be given preference. It is well known that some species of plants develop a shallow root system when propagated from branch cuttings.

BLIGHT RESISTANCE IN VARIETIES OF P. USSURIENSIS

The results obtained from the inoculation work with the leading cultivated varieties of *P. ussuriensis* are presented in Table III. These are the most important varieties of this species grown in northern China, and were propagated by grafting from scionwood collected and brought to this country by the writer. The results herewith presented should not be confused with those presented in Table II, which were obtained from the *seedlings* of some of these varieties. Since these were propagated by grafting, all the trees belonging to any one variety are identical.

TABLE III. INOCULATION RESULTS FROM CULTIVATED VARIETIES OF PYRUS USSURIENSIS
(Grafted trees)

VARIETIES	Age of trees.	Number of years inoculated.	Number of dates on which inoculated.	Tip inoculations: Total number of trees inoculated in tips.	Tip inoculations: Total number of tip inoculations.	Tip inoculations: Percent of trees infected in tips.	Tip inoculations: Extent of tip infection.	Trunk inoculations: Total number of trees inoculated on trunks.	Trunk inoculations: Total number of trunk inoculations.	Trunk inoculations: Percent of trees infected on trunks.	Trunk inoculations: Extent of trunk infection.
						%				%	
Ba Li Hsiang	1-5	5	26	30	79	.0		25	113	.0	
Chien Pa	1-4	4	15	28	71	.0		10	49	.0	
Hsiang Sui	1-5	5	38	77	198	3.9	Tip infection 4 to 5 inches	34	130	.0	
Huang Hsiang Sui	1-5	5	25	21	61	.0		15	53	.0	
Hung Guar	1-5	4	18	38	89	.0		12	55	.0	
Lo Suan	1-4	4	16	23	40	9.1	Tips blighted 2 to 3 inches	7	33	14.3	1 small superficial bark canker.
Ma Ti Huang	1-5	5	24	24	68	.0		12	44	.0	
Mien Suan	1-5	5	19	15	32	.0		11	40	9.1	1 tree girdled 3 inches to diameter .2 inch.
Ta Tou Huang	1-4	4	15	15	44	.0		7	27	.0	
Chieh Li	1-5	7	45	77	202	11.7	Tips blighted 1 to 4 inches	34	107	9.0	2 trees killed to diameter .5 inch.
Chiu Tze	1-4	4	20	16	32	81.2	Killed from 5 to 20 inches	10	29	90.0	Killed to stock to diameter 1.1 inch.
Hau Kai	1-2	2	3	3	6	100.0	From 1 inch into trunk to diameter .35 inch	0	0	.0	
Kuan Hung	1	1	1	1	3	100.0	Blighted to rootstock	0	0	.0	
Man Yuan Hsiang	1-5	5	21	16	43	93.1	Killed 2 to 30 inches to diameter .4 inch	9	32	11.1	Killed to diameter .5 inch.
Nai Tze Hsiang	1-2	2	3	3	5	100.0	Blighted 10 inches into trunk to .7 inch diameter	0	0	.0	
Nan Li	1-2	2	9	7	8	85.7	Killed 8 to 18 inches	3	9	66.7	Killed 5 inches.
Ping Li (Ovoid type)	1-5	5	21	29	71	.0		16	68	12.5	2 trees killed. 1 tree diameter 1.74 inches.
Suan Li	1-3	2	4	3	5	100.0	Killed 4 to 17 inches	1	2	100.0	2 small cankers.
Ta Mo Pan	2-4	3	6	7	23	85.7	Killed from 7 to 24 inches	3	15	.0	
Tang Li	1-5	5	24	22	54	.0		17	57	6.0	1 tree killed diameter 1.75 inches.
Ta Suan	1-5	5	19	19	42	94.7	Tips blighted 2 to 30 inches	13	42	23.1	Killed to diameter of 1 inch.
Tzu Ma Li	1-5	3	8	8	11	87.5	Blighted 6 to 30 inches	4	12	25.0	Killed to diameter of 1.1 inches.

The table has been divided into two parts, the first part giving results from the nine most resistant varieties and the second those from the more susceptible varieties.

Six of these varieties: Ba Li Hsiang, Chien Pa, Huang Hsiang Sui, Hung Guar, Ma Ti Huang, and Ta Tou Huang, have proved immune. None of the inoculations in either tips or trunks developed the disease. These are the only cultivated varieties of any species, in our entire collection, which have proved immune. One other variety, Hsiang Sui, has also shown a remarkable degree of resistance, since only three trees out of seventy-seven blighted for a distance of only four to five inches in

Fig. 14. Showing terminal growth of Japanese Sand Pear *(P. serotina)* on left, and that of *P. ussuriensis* on right. Note the terminal rosette of twisted leaves on *P. ussuriensis.*

the tender tips, and all the trunk inoculations failed. The results show that this variety is usually immune, but will blight very slightly under exceptional conditions of growth or weather. It is fortunate that this has proved so resistant, as it is one of the two best flavored varieties in this species, and possesses soft, juicy flesh which is free from grit cells except a small number around the core. Another variety, Mein Suan, proved immune in the tips and only one small tree blighted in the trunk, which was girdled for a distance of three inches to a diameter of one-fifth inch. Two trees of Lo Suan blighted in the tips for a distance of two to three inches and one tree produced a small superficial bark canker which readily healed over without the slightest injury to the tree.

In the second group we have placed those varieties of *P. ussuriensis* which have proved most susceptible. One of these, Chieh Li, must, however, be classed as highly resistant. While 11.7 percent of the tip inoculations of this variety were successful, the tips blighted for a distance of only one to four inches. In the trunks only two trees out of thirty-four blighted, and these small trunks were killed to a diameter of only one-half inch. This happened during a period of unusually wet, warm weather. Two other varieties, Ping Li and Tang Li, have so far proved

Fig. 15. Typical trunk of old tree of *P. ussuriensis.*

immune in tips, and only one tree of Tang Li blighted in the trunk, while two Ping Li trees were killed as a result of trunk inoculations. It is remarkable that these varieties should prove immune in the tips and occasionally blight in the trunks. It is even more remarkable that these trees should resist all trunk inoculations during the first four years and then blight while making their fifth season's growth.

The other varieties have blighted readily in the young tips, and most of them also in the young trunks. In three varieties no trees were available for trunk inoculation work, and in some of the others such inoculations have been limited. None of the trees tested were more than five years old. It is probable that as the trees grow older some of the varieties will show a higher degree and others a lower degree of resistance, especially in the trunks.

While *P. ussuriensis* has given us the only immune varieties up to the present time, the results show that the species is quite variable, the several varieties ranging from immune to highly susceptible.

Fig. 16. Grove of wild *P. ussuriensis* trees in extreme northern China.

BLIGHT RESISTANCE IN P. USSURIENSIS HYBRIDS

The writer found eleven varieties of pears in northern China and Manchuria which are apparently *P. ussuriensis* hybrids. While there is no record of their origin, their botanical characters indicate that they are hybrids between *P. ussuriensis* and some other species, probably *P. phaeocarpa*. This group includes the most popular varieties grown in northern China. The inoculation results obtained with these are presented in Table IV.

Not one of these varieties has proved immune. In fact, all of them gave a very high percentage of infection in the tips of young shoots. In six varieties—E Li, Fo Chien Hsi, Mi Li, Pan Chen Ssu, Russet Tang Li, and Yarr Li—100 percent of the tip inoculations were successful. In

TABLE IV. INOCULATION RESULTS FROM PYRUS USSURIENSIS HYBRIDS
(Grafted trees)

VARIETIES	Age of trees.	Number of years inoculated.	Number dates on which inoculated.	Tip inoculations				Trunk inoculations			
				Total number of trees inoculated in tips.	Total number of tip inoculations.	Percent of trees infected in tips.	Extent of tip infection.	Total number of trees inoculated on trunks.	Total number of trunk inoculations.	Percent of trees infected on trunks.	Greatest extent of trunk infection.
						%				%	
E Li	1-3	3	10	10	24	100.0	Blighted 8 to 36 inches	5	20	100.0	Killed to stock to diameter 1 inch.
Fo Chien Hsi	1-2	2	7	9	27	100.0	Blighted 10 to 33 inches	1	4	100.0	Killed to stock. Diameter 1 inch.
Hung Li	1-4	2	22	21	43	95.2	Blighted 3 to 28 inches	15	30	33.3	Killed to diameter .9 inch.
Ma Li	1-4	4	14	13	24	92.3	Blighted 6 to 35 inches	8	21	50.0	Killed to diameter .5 inch.
Mi Li	1-4	4	6	9	15	100.0	Blighted 7 to 19 inches	11	27	27.3	Killed to diameter 1.2 inches.
Pai Li	1-4	4	21	20	58	75.0	Blighted 1 to 17 inches	16	57	12.5	Killed to diameter .3 inch.
Pan Chen Ssu	1-4	4	5	6	16	100.0	Blighted 2 to 8 inches	2	6	100.0	Two small cankers.
Ping Ding	1-4	4	18	15	30	86.7	Blighted 4 to 27 inches	6	18	50.0	Killed to scion to diameter 1.2 inches.
Tang Li-Russet type	1-2	2	6	9	21	100.0	Blighted 4 to 41 inches	2	6	100.0	Killed 16 inches to diameter .5 inch.
Tzu Ma	1-3	3	8	8	11	87.5	Blighted 6 to 30 inches	4	12	25.0	Killed to stock to diameter 1.1 inches.
Ya Kuang Li	1-3	4	19	18	49	83.3	Blighted 2 to 36 inches	7	20	14.3	Killed to diameter .5 inch.
Yarr Li	1-2	3	8	8	24	100.0	Blighted 22 to 60 inches	2	3	100.0	Killed to diameter .9 inch.

the other five varieties—Hung Li, Ma Li, Pai Li, Ping Ding Li, and Ya Kuang Li—from 75 to 95 percent of the trees blighted in the tips. The extent of tip infection varied from eight inches in Pan Chen Ssu to sixty inches in Yarr Li. Pai Li gave the smallest percentage of infections and the tips in this variety blighted only from one to seventeen inches.

These varieties show much greater variation in the trunk than in the tip infections, the percentage ranging from 12.5 percent in Pai Li, the most resistant, to 100 percent in the most susceptible.

It is indeed fortunate that Pai Li, the finest flavored variety the writer found in China, has shown the lowest percentage of infected trees in this group of hybrids. Only two small trees were infected in the trunks and these were killed to a diameter of only .3 inch. The fruit is small to medium in size, with tender, juicy, delicious flesh containing few grit cells. It should prove valuable in breeding work. In this group Ya Kuang Li ranks second and Mi Li third in resistance. The former is a variety of good quality when grown in northern China, but in the dry summer climate of Southern Oregon the fruit produced is of very poor quality. Hung Li and Yarr Li are the two most widely grown varieties of northern China. In our work the former proved moderately susceptible and the latter highly susceptible in the trunks. The other varieties tested show a high degree of susceptibility. These are of strictly secondary importance in China and apparently promise nothing to the American pear industry.

BLIGHT RESISTANCE IN MOST RESISTANT VARIETIES OF PYRUS COMMUNIS AND ITS HYBRIDS

Inoculation results obtained from the most resistant varieties of *Pyrus communis* and its hybrids are presented in Table V. These were propagated by grafting, and the trees should not be confused with seedlings of these varieties.

We have placed them in a separate group since they have shown a higher degree of resistance to blight than the other varieties belonging to this species, and some of them appear to be of special value as resistant body stocks for our commercial pears. While these are regarded as the most resistant varieties of this species, a glance at the table will indicate that none of them are immune. There is also great variation among the several varieties. The tip infections ranged from 31.2 percent in Douglas to 100 percent in Kieffer. The three varieties most resistant in the tips were Douglas with 31.2 percent, Farmingdale with 45.6 percent, and Old Home with 50 percent infection. In seven varieties; namely, Burkett, Lemon, Longworth, Orel, Serrulata No. 479, Tolstoy, and Variolosa, from 52.6 to 75 percent of the inoculations were successful. Estella and Kieffer showed 83.3 and 100 percent respectively.

The extent of tip infection was least in Douglas, Farmingdale, and Tolstoy, and greatest in Burkett, Estella, Lemon, Old Home, Orel, Surprise, and Variolosa. The extremes of infection are given and each variety shows considerable variation. In a vast majority of these cases the extent of infection was comparatively small.

The results obtained from trunk inoculations in these varieties are very important and should be carefully studied. The percentage of trunk infection varies from nothing in Farmingdale to 69.1 percent in Burkett.

TABLE V. INOCULATION RESULTS FROM MOST RESISTANT VARIETIES OF P. COMMUNIS AND ITS HYBRIDS
(Grafted trees)

VARIETIES	Age of tree.	Number of years inoculated.	Number of dates on which inoculated.	Tip inoculations: Total number of trees inoculated in tips.	Total number of tip inoculations.	Percent of trees infected in tips.	Extent of tip infection.	Trunk inoculations: Total number of trees inoculated on trunks.	Total number of trunk inoculations.	Percent of trees infected in trunks.	Percent of trees with cankers only.	Percent of trees with light trunk infections	Percent of trees with medium trunk infections.	Percent of trees with heavy trunk infections.
						%				%	%	%	%	%
Burkett	2-8	9	23	15	109	73.3	2 to 36 inches	51	226	69.1	21.5	7.9	8.0	31.7
Douglas	2-5	7	18	16	48	31.2	2 to 5 inches	43	211	65.0	37.2	.0	4.6	23.2
Estella	1-7	9	19	18	84	83.3	3 to 30 inches	57	250	17.5	15.8	.0	1.7	.0
Farmingdale	1-2	2	8	29	134	45.6	1 to 7 inches 2 trees 10 and 17 inches	17	102	.0	.0	.0	.0	.0
Kieffer	2-5	5	11	11	49	100.0	14 to 22 inches	28	129	50.0	32.1	.0	3.6	14.3
Lemon	1-7	6	17	34	154	61.7	1 to 14 inches 1 tree 24 inches 1 tree 36 inches	41	173	26.8	14.6	.0	.0	12.2
Longworth	1-9	9	22	31	115	74.2	1 to 24 inches	41	156	26.7	21.9	4.8	.0	.0
Old Home	1-8	9	46	66	209	50.0	2 to 30 inches 1 tree 46 inches 1 tree 72 inches	187	646	12.2	8.0	2.6	.0	1.6
Orel	1-7	10	26	32	134	56.2	2 to 36 inches 1 tree 54 inches	104	481	66.4	12.5	2.9	1.0	50.0
Serrulata No. 479	2-8	9	26	21	90	61.9	2 to 24 inches	22	96	40.9	40.9	.0	.0	.0
Surprise	1-7	9	37	31	119	77.4	2 to 36 inches	168	774	63.1	42.3	.0	3.0	17.2
Tolstoy	1-8	5	17	19	79	52.6	12 to 15 inches	28	130	3.6	3.6	.0	.0	.0
Variolosa	1-9	10	46	56	269	75.0	2 to 30 inches 1 tree 54 inches	88	484	29.5	22.7	4.5	.0	2.3

Fig. 17. Fruit and leaves of *P. betulaefolia*. (Natural size.)

The following seven varieties have shown a very high degree of resistance in the trunks: Estella, Farmingdale, Longworth, Old Home, Serrulata No. 479, Tolstoy, and Variolosa. Farmingdale has shown the highest resistance, with no infection in the trunks. This result should not be regarded as final, however, since the trunk inoculations have been confined to one season's work and to two-year-old trees. It is possible that under exceptional weather conditions the inoculations might be successful. Nevertheless, it now seems probable that this will prove very resistant, since it is the only cultivated variety of *P. communis* which has shown immunity to blight in two-year-old trunks. It has shown a remarkable degree of resistance in the tips; all the infections, with two exceptions, have been confined to the upper one to seven inches of the shoots. In one shoot the disease ran down ten and in another shoot seventeen inches. Furthermore, on the rich soils of central Illinois, where the Farmingdale originated and where blight is exceptionally

Fig. 18. Typical leaf of *P. betulaefolia.*

severe, it has shown no natural infections. Extensive inoculation work will be done with this variety during the coming years and if it continues to show an equal degree of resistance it will doubtless prove quite valuable.

Tolstoy, a hybrid between *P. communis* and *P. ovoidea,* originated by Prof. N. E. Hansen at the South Dakota Experiment Station, ranks second in resistance in this group. Only one tree, 3.6 percent, has blighted in the trunk, and these infections consisted of superficial bark cankers which quickly healed over without injuring the tree in the slightest degree. The fruit of this new variety has proved worthless in Southern Oregon, owing to its small size and poor flavor. The young trees in the nursery make a slow growth, but make a good growth when transplanted to the orchard, especially on very fertile soil. If this variety shows sufficient vigor under diverse soil conditions it may prove valuable as a stock for top-working.

In this group Old Home ranks third in resistance. While 12.2 percent of the inoculated trunks blighted, 8 percent of these trees developed only superficial bark cankers which readily healed over. In five trees, or 2.6 percent, the infections were classed as light, with less than one-third of the young trunks blighted. Three trees, or 1.6 percent, developed heavy trunk infections. Two of these trees were small, and quite young, while one was three years old, with a diameter of one and one-half inches. In the latter tree the disease did not extend to the rootstock. The trees have been repeatedly inoculated under various conditions and at different seasons of the year. The extremely small number of infections obtained during nine years' work indicates that only in very rare instances can this variety be infected in the trunk and larger wood. The fruit is of poor quality; hence this variety is of value only as a stock for top-working and possibly for breeding purposes. As a stock for top-working it seems exceptionally promising, for it is the most vigorous grower in our collection and the tree develops a sturdy framework and perfect form. This variety is a pure *P. communis* and like Farmingdale it originated in central Illinois.

While Estella has shown a slightly higher total percentage of infection than Old Home, it has shown a smaller percentage of severe trunk infection than the latter. In this variety, with the exception of one tree, all of the trunk infections have been superficial bark cankers, and in this single exception less than two-thirds of the young trunk was killed. This variety is a seedling of Kieffer, hence a cross between *P. communis* and *P. serotina.* The fruit is of very poor quality. The tree is a good grower on fertile, mellow soils, and a moderate grower on heavy clay soils. On heavy soil it is not nearly as vigorous as Old Home. It is also injured by excessive amounts of lime in the soil, and is inferior to Old Home as a stock for top-working.

Although Longworth has shown a considerably higher total percentage of trunk infections than either Old Home or Estella, it has given a smaller percentage of medium and heavy trunk infections than either of those varieties. While it shows 26.7 percent total infections, all of these except in two trees consisted of superficial bark cankers. In small two-year-old trees the trunks were killed to a diameter of one-half inch. This variety may be classed as highly resistant in the trunks, and quite vigorous, although it is not as vigorous as Old Home. The tree, however, possesses one fault: the trunk, at least in Southern Oregon, is subject to winter injury. In 1919 with a temperature of ten degrees below zero, and again in 1924 with two degrees above, considerable bark splitting occurred on the trunks. This is

remarkable, since the variety originated in Iowa and is hardy there. The injury experienced here may be due to the usual mild winter weather, followed on these two occasions by exceptionally severe temperatures. It is evidently hardy in a much colder but more constant climate. It is unfor-

Fig. 19. Large tree of *P. betulaefolia* in Shantung Province, China.

tunate that it shows this weakness under local conditions; otherwise it would probably be very valuable as a blight-resistant stock. Until we have further evidence regarding its hardiness it cannot be recommended for that purpose. The fruit is of poor quality. While we have no record of the ancestry of

Longworth, it is chiefly *P. communis,* but evidently is an attenuated hybrid with a small amount of Oriental blood.

Variolosa is another variety which has shown a gratifying degree of resistance to blight. While this is classed by botanists as a species, and the name as a synonym of *P. pashia,* the type which we have is unquestionably distinct from that species. It appears to be a hybrid between *P. pashia* and *P. communis* and the seedlings are variable. For the reason stated above, the writer has classed it with this group of varieties rather than with the species. Although the percentage of infected trees is 29.5 percent, the vast majority of these, 22.7 percent, developed only superficial bark cankers which did not injure the trees. Four of the young trees showed light trunk infections. Two trees, or 2.3 percent, developed heavy trunk infections. One of these was a small two-year-old tree which blighted severely. The other was a six-year-old tree with a trunk diameter of 2.4 inches and was killed to two inches above the rootstock. Why this one tree should blight severely and the other four of the same age, growing under identical conditions, thoroughly inoculated on the same dates and with the same blight culture, should remain immune, is a mystery. Furthermore, the trunk of this tree had resisted all attempts to infect it during previous years.

Five years ago we top-worked fifty trees of Variolosa with Anjou, Bosc, Bartlett, Comice, and Winter Nelis to determine whether these susceptible varieties would influence the degree of resistance of Variolosa. During the last two years the Variolosa trunks of these trees have been repeatedly inoculated and all of them have proved highly resistant. In a few instances small superficial bark cankers were produced on the young trunks, but none of these caused any material injury. Trunks of these top-worked trees proved as resistant to blight as Variolosa check trees of the same age which had not been top-worked. It is evident from these results that the resistant trunk of this variety is not rendered more susceptible to blight as a result of being top-worked with our five leading commercial blight-susceptible varieties.

In two cases the Bartlett and Bosc tops were inoculated with Pear Blight and blighted down to the Variolosa stock. In one tree the disease stopped at the union, and in the other it extended only an inch and a half below the union into the Variolosa stock. This of course is a severe test, since the Bartlett and Bosc tops are extremely susceptible, blighted vigorously above the union, and consequently millions of bacteria were massed at the union. The fact that the Variolosa framework could withstand this mass action of millions of bacteria brings out clearly its high degree of resistance.

Variolosa appears very promising as a framework stock for top-working. It is a vigorous grower, although not equal to Old Home in this respect, develops a clean, strong, well formed framework, and has proved perfectly hardy in Southern Oregon, and at the Arnold Arboretum near Boston, Mass. When Anjou, Bartlett, Bosc, Comice, and Winter Nelis are top-worked to this stock the union is smooth and strong; the scion maintains the same size as the stock below it, and the tops make a very vigorous growth.

In this group we have placed a certain type of *P. serrulata* which is designated as Serrulata No. 479. It was obtained from the Arnold Arboretum under this number and was grown from seed collected in China by Mr. E. H. Wilson. This particular type has proved very resistant, while his other types of that species have proved quite susceptible to blight at the Southern Oregon Station. Slightly more than 40 percent of the inoculations on the trunks of this type proved successful, but not a single infection extended

Fig. 20. Typical trunk of old tree of *P. betulaefolia.*

beyond the canker stage. These were of small size in the majority of cases, and in all cases they were confined to the outer bark and healed over quickly. For nine years the work has been conducted with trees from two to eight years old and every effort has been made to kill them, but the severest infections resulted in bark cankers only.

Although designated by the Arboretum as *P. serrulata,* this is evidently a hybrid between *P. serrulata* and *P. betulaefolia.* It produces extremely small, worthless fruit, similar to that borne by *P. betulaefolia.* The young trees are only moderate growers in the nursery, but become more vigorous with age, and in the orchard develop a good, strong framework for top-working. Serrulata No. 479 has not yet been top-worked with any of our commercial varieties, but it will be thoroughly tested for that purpose in the future. Botanically it cannot be classed in this group, but it has been placed here because of its possible value as a framework stock, for which purpose this group of varieties is most suitable.

Lemon is another variety which has shown a moderate degree of resistance, although it is not nearly as resistant as the varieties just discussed. A total of 26.8 percent of the trees were infected, but 14.6 percent of them developed only bark cankers. The heavy trunk infections amountd to 12.2 percent. This is a rather high percentage of trunk infection; at the same time, it possesses other desirable characteristics. It is a variety of *P. communis,* a native of Russia, and has proved hardy as far north as Ottawa, Canada. In cold regions it may prove hardier than any of the other resistant varieties. It is also a vigorous grower and develops a strong, well shaped framework suitable for top-working. The fruit is of poor quality.

Of the remaining five varieties, Burkett, Douglas, Orel, and Surprise have shown a high degree of resistance under natural conditions in the Mississippi Valley, a region where blight is very severe. Kieffer has for many years been known as moderately resistant to this disease. These five varieties have shown a high total percentage of infection, and also a high percentage of heavy infections.

The inoculation results obtained from Douglas, Orel, and Surprise have proved extremely interesting in one respect; namely, that these varieties appear to be far more resistant in the young shoots than in the trunks. In Douglas and Orel the total percentages of trunk infections were considerably higher than the tip infections, and in all three varieties the trunk infections usually proved far more severe than the tip infections. The vast majority of tip infections were slight, usually killing the young, vigorous shoots for a distance of only two to twelve inches, and in a very high percentage only two to six inches. On the other hand, the infections resulting from inoculations made directly into the larger and older wood of the trunks, which were from three-fourths of an inch to two inches in diameter, proved severe, particularly in Orel. At present it is impossible to explain why the disease, in the vast majority of cases, did not progress very far through the young shoots, but killed many of the trunks when injected directly into them. Evidently the young shoots, for some unknown reason, possess a factor for resistance which is either absent or not so highly developed in the older wood.

Under natural conditions blight infection usually develops first in either the young, tender wood or in the blossoms, and the fact that these varieties have remained remarkably free from severe blight injury in the Middle West is probably due to the resistance of the younger portions of the tree. It is

not due to high resistance in the older wood. In this respect they differ from our well known commercial pears, in which the youngest wood usually blights most readily.

It is evident, therefore, that a variety which shows very little natural infection under field conditions is not necessarily resistant in the older wood and thus suitable as a body stock for our susceptible commercial varieties. These commercial varieties often blight readily to the stock, and if the stock is not resistant in the older wood the disease progresses into it and destroys it. Hence the great importance of artificially inoculating a promising variety in the larger and older wood before recommending it as a blight-resistant body stock. The results from tip inoculations alone are not sufficient. For example, Orel has proved much more resistant in the young shoots than either Estella, Longworth, or Variolosa, but its susceptibility in the trunks is far more marked than in these latter varieties.

BLIGHT RESISTANCE IN SUSCEPTIBLE VARIETIES OF P. COMMUNIS AND ITS HYBRIDS

Table VI gives the inoculation results obtained from the more susceptible American and European varieties. This list consists of *P. communis* varieties with the exception of Abraham, Conkleton, Gogol, and Siebold, which are *P. communis* hybrids, and Pineapple, which is a Chinese variety of uncertain origin, probably *P. serotina.*

It is evident from the table that the vast majority of varieties in this list are so highly susceptible to blight that no discussion of them is necessary. The work with some of them has been too limited to make the results conclusive. These results are included here because they are indicative, and as a matter of record.

The following varieties in this group have shown far greater resistance than the others: Conkleton, Durand, Early Harvest, German Sugar, Hafraths Birne, Horns Winter, Miller, Pineapple, Siebold, Snyder, Stout, Warner, and Wilkinson. In fact, Conkleton, Horns Winter, and Pineapple have shown a very high degree of resistance, and if they possessed other desirable characteristics would have been included in Table V. The fruit of these three varieties is worthless in Southern Oregon. The trees are slow growers on our heavy soils, and Pineapple is subject to winter injury during our coldest winters.

The work with two of the varieties in this list, Lincoln and Snyder, has not been sufficient to justify conclusions. While these two varieties blight readily in the young wood when inoculated, the fact that natural infections on these in the variety orchard have been few and confined to small wood indicates that the older wood is probably resistant. The inoculation work with these varieties will therefore be continued.

TABLE VI. INOCULATION RESULTS FROM SUSCEPTIBLE P. COMMUNIS VARIETIES AND HYBRIDS

(Grafted trees)

VARIETIES	Age of trees.	Number of years inoculated.	Number of dates on which inoculated.	Tip inoculations: Total number of trees inoculated in tips.	Tip inoculations: Total number of tip inoculations.	Tip inoculations: Percent of trees infected in tips.	Tip inoculations: Extent of tip infection.	Trunk inoculations: Number of trees inoculated on trunks.	Trunk inoculations: Total number of trunk inoculations.	Trunk inoculations: Percent of trees infected in trunks.	Trunk inoculations: Percent of trees with light trunk infection.	Trunk inoculations: Percent of trees with medium trunk infection.	Trunk inoculations: Percent of trees with heavy trunk infection.	
						%				%	%	%	%	
Abraham	2-3	3	3	2	4	100.0	36 to 38 inches	6	12	66.7	16.7	.....	50.0	.....
Alberta	1-5	2	3	7	13	100.0	Killed	2	4	100.0	.....	.....	100.0	2 trees killed
Alkire	2-3	2	2	.....	.....	.....	.....	4	14	100.0	.....	.....	100.0	4 trees killed
Amanlis Panache	5	1	3	1	5	100.0	30 to 36 inches	3	21	33.3	.....	.....	33.3	1 tree killed
Ayer	2	2	2	1	5	100.0	16 inches	2	8	100.0	.....	.....	100.0	2 trees killed
Beaumont	3	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1 tree killed
Besi de La Motte	1-5	5	7	6	8	100.0	4 inches to trunk	14	42	92.8	35.7	7.1	50.0	7 trees killed
Bessimianka	1-5	5	16	13	25	100.0	16 inches to stock	26	76	100.0	3.8	3.8	92.3	24 trees killed
Beurre Gris	3	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1 tree killed
Beurre Oudinot	1-6	2	2	3	3	100.0	Killed	4	8	100.0	.....	.....	100.0	4 trees killed
Bilboa	1	1	1	2	2	100.0	Killed	.....	.....	.....	.....	.....	.....	.....
Blanque Precoce	4	1	1	.....	.....	.....	.....	2	6	100.0	.....	.....	100.0	2 trees killed
Blickling	2-6	2	3	2	5	100.0	24 inches	2	6	100.0	.....	.....	100.0	2 trees killed
Bonne de Malines	6	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1 tree killed
Bordeaux	3-4	2	2	.....	.....	.....	.....	12	48	100.0	.....	.....	100.0	12 trees killed
Citron de Carmes	1-3	3	4	7	15	100.0	14 inches to trunk	3	9	100.0	66.7	.....	33.3	1 tree killed
Comte de Paris	5	1	1	.....	.....	.....	.....	1	1	100.0	.....	.....	100.0	1 tree killed
Conkleton	1-8	8	17	4	56	100.0	2 to 28 inches	4	95	50.0	25.0	25.0	0.0	Outer bark canker
Crocker Bartlett	1-2	2	2	5	11	80.0	Killed to stock	.....	.....	.....	.....	.....	.....	.....
Diel	2	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1 tree killed
Duchess Precoce	1	1	1	3	3	100.0	10 to 27 inches	.....	.....	.....	.....	.....	.....	.....
Durand	2-5	5	6	2	12	100.0	10 inches	7	27	57.1	42.8	.....	14.3	.....
Early Harvest	1-7	7	13	16	57	100.0	2 to 60 inches	34	108	47.0	29.4	.....	17.6	6 trees killed
Effie Holt	1-5	6	8	6	28	83.3	6 to 48 inches	11	32	72.7	.....	.....	72.7	8 trees killed
Espargne	2	1	1	3	9	100.0	Killed.	.....	.....	.....	.....	.....	.....	.....
Fauke Tivule	3-4	3	3	.....	.....	.....	.....	10	30	100.0	.....	.....	100.0	10 trees killed
Favorita	1-2	2	2	4	4	100.0	10 inches to stock	.....	.....	.....	.....	.....	.....	.....
Figue	5	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1 tree killed
Fluke	2-6	5	7	6	28	83.3	4 to 24 inches	13	42	100.0	23.0	.....	76.9	6 trees killed
Fontenay	1	1	1	3	3	100.0	Killed	.....	.....	.....	.....	.....	.....	.....
Forelle	2-5	6	22	22	76	100.0	Killed	20	70	100.0	.....	.....	100.0	20 trees killed
Fox	1-2	2	2	4	10	100.0	3 inches to stock	.....	.....	.....	.....	.....	.....	.....
General de la Moi	5	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1 tree killed

German Sugar	7	7	23	19	63	84.2	1 to 40 inches	56	227	60.7	17.8	1.8	41.1	4	trees killed
Giffard	5	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1	tree killed
Gogol	4-6	3	7	4	34	50.0	5 to 12 inches	4	64	75.0	25.0	.....	50.0	.....	
Gold Nugget	1-4	4	6	2	10	100.0	Killed	5	25	100.0	20.0	.....	80.0	2	trees killed
Goubault	5	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1	tree killed
Graslin	5	1	1	.....	.....	.....	.....	2	6	100.0	.....	.....	100.0	2	trees killed
Guyot	2-4	4	4	1	3	100.0	Killed to trunk	5	15	100.0	.....	.....	100.0	5	trees killed
Hafrath's Birne	3-6	4	6	3	15	100.0	Killed to trunk	22	79	45.4	9.1	.....	36.4	5	trees killed
Hardy	2-6	3	6	8	20	87.5	3 to 48 inches	6	39	100.0	.....	.....	100.0	6	trees killed
Heyst	1	1	1	5	5	100.0	Killed	.....	.....	.....	.....	.....	.....	.....	
Horns Winter	1-7	7	15	9	29	66.7	9 to 46 inches	26	71	26.9	7.7	7.7	11.5	1	tree killed
Hourdequin	3-4	2	2	.....	.....	.....	.....	2	6	100.0	.....	.....	100.0	2	trees killed
Idaho	3-5	2	2	2	6	100.0	Killed	3	9	100.0	.....	.....	100.0	3	trees killed
Joan de Arc	1-4	3	3	5	5	100.0	Killed	7	21	100.0	.....	.....	100.0	7	trees killed
Kincaid	3	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1	tree killed
Koonce	3-4	1	3	3	7	100.0	1 inch to ground	.....	.....	.....	.....	.....	.....	.....	
Krull	2	2	3	2	5	100.0	3 to 24 inches	2	11	100.0	.....	.....	100.0	.....	
Kurskya	1-5	5	8	6	12	100.0	12 to 36 inches	20	70	90.0	5.0	.....	85.0	17	trees killed
Lincoln	1-2	3	3	7	17	100.0	1 inch into trunk to diameter .7 inch	.....	.....	.....	.....	.....	.....	.....	
Louise Bonne	2	1	1	3	9	100.0	Killed	.....	.....	.....	.....	.....	.....	.....	
Lucy Duke	2-3	3	4	.....	.....	.....	.....	10	22	100.0	.....	.....	100.0	3	trees killed
Madame Chervet	6	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1	tree killed
Margaret	2	1	1	3	9	100.0	Killed	.....	.....	.....	.....	.....	.....	.....	
Mendel	1-2	2	4	10	30	77.7	12 to 22 inches	4	24	100.0	.....	.....	100.0	3	trees killed
Miller	1-5	5	8	5	17	20.0	5 to 34 inches.	12	36	25.0	16.7	.....	8.3	1	tree killed
Mormon	1-5	5	8	8	24	100.0	36 to 72 inches	9	25	77.8	.....	.....	77.8	1	tree killed
Olivier	5	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1	tree killed
Pineapple	1-4	6	10	16	49	87.5	6 to 30 inches	12	44	8.3	8.3	.....	.....	.....	
Pound	1-2	2	2	5	11	60.0	Killed to ground	.....	.....	.....	.....	.....	.....	.....	
Pratt	4	1	1	.....	.....	.....	.....	4	8	100.0	.....	.....	100.0	4	trees killed
Precoce de Angiers	5	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1	tree killed
President Drouard	1-3	3	4	7	15	100.0	Killed	4	20	100.0	.....	.....	100.0	4	trees killed
President Roosevelt	3-4	3	3	.....	.....	.....	.....	13	36	100.0	.....	.....	100.0	13	trees killed
Rossney	1-5	4	5	5	5	100.0	Killed	9	27	100.0	.....	.....	100.0	9	trees killed
Santa Claus	2	1	1	5	5	100.0	Killed	.....	.....	.....	.....	.....	.....	.....	
Seckel	2-4	4	6	5	19	100.0	24 inches to trunk	8	30	100.0	12.5	.....	87.5	4	trees killed
Sheldon	1-2	2	2	4	8	75.0	Killed	.....	.....	.....	.....	.....	.....	.....	
Siebold	1-5	4	7	4	10	100.0	2 to 26 inches	26	96	34.6	.....	.....	34.6	.....	
Smyth	2-5	3	4	2	5	100.0	6 to 36 inches	4	14	100.0	50.0	.....	50.0	.....	
Snyder	1-2	2	2	5	11	80.0	6 to 16 inches	.....	.....	.....	.....	.....	.....	.....	
Stout	2-3	3	5	2	8	100.0	12 inches to trunk	4	12	25.0	.....	.....	25.0	1	tree killed
Superb	3-5	3	4	3	6	100.0	10 to 24 inches	3	14	100.0	.....	.....	100.0	1	tree killed
Tedrow Beauty	2-4	2	4	.....	.....	.....	.....	4	16	75.0	.....	.....	75.0	3	trees killed
Tongres	1-5	4	6	5	5	100.0	Killed	17	55	100.0	.....	.....	100.0	17	trees killed
Triomphe de Dives	5	1	1	.....	.....	.....	.....	1	3	100.0	.....	.....	100.0	1	tree killed
Tyson	1-3	3	3	5	11	40.0	14 inches to trunk	1	3	100.0	.....	.....	100.0	1	tree killed
Vermont Beauty	2	1	1	1	5	100.0	30 to 48 inches	1	1	100.0	.....	100.0	.....	.....	
Vicar of Wakefield	2	1	1	3	9	100.0	Killed	.....	.....	.....	.....	.....	.....	.....	
Vienna	3-6	2	2	.....	.....	.....	.....	2	6	100.0	.....	.....	100.0	1	tree killed
Warner	2-5	5	9	4	16	100.0	3 to 36 inches	15	46	53.3	13.3	13.3	26.7	2	trees killed
Wilkinson	1-5	4	8	7	17	42.8	8 inches to trunks	12	38	41.7	8.3	.....	33.3	3	trees killed
Zink	1	1	1	5	5	100.0	2 to 16 inches	.....	.....	.....	.....	.....	.....	.....	

Fig. 21. Tree of *P. betulaefolia* growing at edge of pond in northern China.

NATURAL INFECTIONS IN THE VARIETY ORCHARD

Table VII gives a record of the natural infections which have occurred in our extensive variety collection. Since these trees have been infected by natural agencies, this being a matter of chance, the results are not strictly comparable. As the several varieties, however, have received similar treatment otherwise and are confined to a comparatively small orchard in which blight has been very prevalent every year, the results are of considerable value. Furthermore, since a very large percentage of these trees have blighted seriously and many of them have been killed, the results obtained with these particular varieties are probably as valuable as they would be if

Fig. 22. Fruit of the Japanese Sand Pear *(P. serotina)*. Note absence of calyx.

the trees had been artificially inoculated. Since most of these varieties were imported directly from Europe, where blight is unknown, and there is no record in this country regarding their susceptibility or resistance, the results are undoubtedly well worth recording.

The variety orchard is only twelve years old, located on fertile river bottom soil, and has received clean cultivation and irrigation. One hundred and thirty-two varieties or 34 percent of all those in the orchard, have been killed. In two hundred and fifty-two, or 65 percent of the varieties, wood two inches or more in diameter has blighted, three hundred and seventy-seven varieties, or 97 percent, have shown infection. Eleven varieties, or

less than 3 percent, have not blighted. Of these, five varieties, Ayer, Chieh Li, Douglas, Horns Winter, and Longworth, are not immune, as shown by our inoculation results.

Undoubtedly a much larger percentage of the varieties would have been killed if the infections had been left to run their course. The orchard was diligently patrolled during the blight season, and all infections taken out of the trees; most of them before the disease stopped running. Without doubt many more varieties would have been killed if such care had not been exercised. Future reports on this orchard will unquestionably add many varieties to the list of those killed.

Our commercial orchard includes the six leading varieties grown in Southern Oregon. We have lost some trees of each of these varieties. The losses have been greatest in Bosc and Howell. Bartlett and Comice rank second in susceptibility. Anjou and Winter Nelis have suffered least.

TABLE VII. RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

Variety	Age of trees	Number of years blighted	Number of infections	Diameter of largest wood killed	
				in.	
Abraham	11	5	50	4	
Ah Mon Dieu	12	4	9	1½	
Airoles (Leclerc)	10	6	17	1½	
Alamo	8	2	22	5	Tree killed
Alexandre Lucas	12	5	16	4	
Alexandre III	11	2	6	3½	
Alliance Franco Russe	11	1	1	½	
Alphand	11	2	8	1½	
Amanlis Panache	10	3	15	3	
Amelie Baltet	11	0	0	----	
Ananas du Perche	11	3	4	3½	
Andusson	10	1	7	----	Tree killed
Andre Desports	12	2	26	4	
Andrews	10	2	10	2¾	
Angleterre	12	3	24	4	
Angouleme	11	3	8	8	Tree killed
Anne de Bretagne	8	1	7	----	Tree killed
Archangel	12	4	42	4	
Arenberg Colmar	9	2	13	7	Tree killed
Artois	8	1	9	6	Tree killed
Assomption	9	2	50	5	Tree killed
Avocat Tonnellier	11	4	17	3	
Ayer	9	0	0	0	
Bachelier	11	5	26	5	
Bailey	11	4	23	1½	
Barillet	12	3	13	3	
Baronne Leroy	12	3	8	1½	
Bastie	12	3	17	4⅜	
Baudry	10	3	38	6½	Tree killed
Beaumont	9	2	3	3	Tree killed
Beauty	10	3	6	2	
Belle de Beaufort	11	2	5	1½	
Belle de Beugny	11	4	14	1½	
Belle de Julliet	12	4	15	1¾	
Belle de Lesquin	9	3	12	3	Tree killed
Belle de Limoges	9	2	12	4	Tree killed
Belle de Picarde	11	3	18	1	
Benoist	10	3	11	1¼	
Bergamote Arsene Sannier	12	5	55	2½	
Bergamote de Automne	12	4	17	2½	
Bergamote d' Esperen	9	2	2	5	Tree killed
Bergamote d' Ete	11	2	18	1½	
Bergamote Herault	11	3	18	7¼	Tree killed

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

Variety	Age of trees	Number of years blighted	Number of infections	Diameter of largest wood killed	
				in.	
Bergamote Nanot	11	4	24	2⅜	
Bergamote Rene	9	1	8	2¼	
Bergamote Sageret	11	3	11	2	
Besi de Chaumontel	8	2	5	----	Tree killed
Bessimianka	6	1	6	5	Tree killed
Beurre Gris	9	2	12	5½	Tree killed
Blanquet (Longue)	11	4	95	8	Tree killed
Blanquet Precoce	11	2	19	3	
Blickling	8	1	1	4	Tree killed
Blondet	11	4	20	1⅜	
Bloodgood	12	5	33	3⅛	
Boisselot	11	3	8	7½	Tree killed
Bollwiller	10	3	14	1⅜	
Bon Chretien Bonnamour	11	4	22	1¼	
Bon Chretien de Vermont	11	4	47	2½	
Bonnefond	12	3	15	1	
Bonneserre	11	2	24	3	
Bordeaux	11	4	10	2	
Bordillon	11	4	11	2½	
Bouldieu	12	4	30	7	Tree killed
Boussock	12	4	63	5	Tree killed
Brabant	11	4	22	7	Tree killed
Brettonneau	6	1	2	4	Tree killed
Briffaut	11	3	24	1¾	
Brissac	12	4	10	1⅛	
Burkett	11	3	11	1½	
Caen	6	1	2	3⅛	Tree killed
Caissoy D'Hiver	12	4	26	1½	
Canrobert	12	4	28	2	
Carnot	11	3	12	2⅛	
Capiaumont	11	2	22	2½	
Catillac	10	2	12	7	Tree killed
Chandy	11	1	3	¾	
Chantenay	9	2	15	6	Tree killed
Chasseurs	12	2	3	½	
Chieh Li	7	0	0	----	
Choisnard	8	1	3	9	Tree killed
Cincincis	9	0	0	----	
Clairgeau	5	2	15	4	Tree killed
Cognee	12	5	34	3	
Colmar	11	4	29	5	Tree killed
Colmar de Mars	11	2	8	3	
Colonel Marchand	12	5	18	1½	
Columbia	11	2	10	1¼	
Comtesse de Paris	9	2	9	----	Tree killed
Conkleton	11	3	33	1	
Corneau	11	3	11	2	
Cornelis	11	4	9	5	
Craonnaise	8	1	8	5	Tree killed
Crassane	10	3	8	6½	Tree killed
Crocker Bartlett	9	2	5	8	Tree killed
Dalbret	12	5	29	2	
Dana Hovey	8	2	6	5	Tree killed
Defais	10	2	19	6½	Tree killed
De Lacroix	12	4	11	1⅜	
Delices d'Avril	11	3	21	3½	
Delfosse	12	4	20	2	
Derouineau	11	1	3	⅛	
Desportes	12	4	16	1¾	
Diel	12	4	41	3	
Dillen	10	2	24	6½	Tree killed
Directeur Hardy	11	4	20	1½	
Directeur Tisserand	8	1	3	----	Tree killed
Dixie	8	2	3	⅛	
Docteur Joubert	11	3	24	3½	
Dorset	11	4	78	4	

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

Variety	Age of trees	Number of years blighted	Number of infections	Diameter of largest wood killed	
				in.	
Douglas	8	0	0	----	
Douillard	11	4	21	1½	
Doyenne Defais	11	3	16	2	
Doyenne d'Hiver	12	3	20	2½	
Doyenne de la Grifferaye	11	2	9	½	
Doyenne Georges Boucher	11	2	3	¾	
Duchesse Anne	6	1	7	3	Tree killed
Duchesse Bronzee	11	1	2	¼	
Dumont	9	2	3	5	Tree killed
Durand	7	3	38	1	
Easter Bergamote	11	2	17	1½	
Easter Beurre	9	2	8	6½	Tree killed
Early Green Sugar	10	2	3	2	
Early Harvest	10	3	4	1	
Ecully	9	1	1	1¼	
Effie Holt	10	2	6	7	Tree killed
Elenore Liefmans	11	4	5	1½	
Ernest	5	1	1	----	Tree killed
Espargne (de)	11	3	15	6	
Estella	10	4	6	½	
Eva Baltet	11	2	4	½	
Ezee	12	4	7	1	
Fame	10	3	3	7	Tree killed
Fauke Tivule	8	1	6	2½	
Favorita	8	1	1	¾	
Favorite Joanon	11	2	8	1¼	
Felix Sahut	11	3	23	2¼	
Ferron	11	3	13	2	
Fideline	12	3	15	7	Tree killed
Figue	12	1	1	½	
Flemish Beauty	11	3	29	2½	
Flou Aine	9	2	13	6	Tree killed
Forelle	7	2	30	4	Tree killed
Fortunee	12	4	11	1¾	
Fougiere	9	3	19	3	Tree killed
Fouqueray	11	3	15	1½	
Fox	12	5	30	1½	
Francois Coppee	12	4	12	1½	
Fred Clapp	11	4	24	2½	
Fulvie	6	1	7	2½	Tree killed
Gantoise	6	1	3	3½	Tree killed
Garber	9	1	1	½	
General de Villebois	10	2	2	4	Tree killed
General de Villebois Mareuil	10	4	16	2½	
General Galliene	12	3	10	1	
Georges d'Amboise	11	3	13	2½	
German Sugar	11	3	9	1	
Ghelin	10	3	3	5	Tree killed
Ghislain	12	3	22	3	
Giffard	11	2	24	3½	
Gilogil	9	2	26	7	Tree killed
Glou Morceau	8	2	15	5	Tree killed
Gold Nugget	7	3	4	6½	Tree killed
Goubault	9	2	2	3½	Tree killed
Goubault (Doy)	12	2	2	½	
Gratioli	8	1	3	4	Tree killed
Gray Doyenne	12	3	6	1	
Green Sweet	12	3	4	¾	
Griesa No. 1	8	3	6	1¼	
Grosse Louise	11	1	1	1	
Guillard	12	1	4	1	
Guyot	11	2	14	1	
Hampden	12	3	16	7	Tree killed
Hardempont de Automne	8	2	10	5	Tree killed
Hardempont (Ang)	11	2	17	2½	

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

Variety	Age of trees	Number of years blighted	Number of infections	Diameter of largest wood killed	
				in.	
Hardy	12	4	34	10	Tree killed
Harvard	9	2	15	5¼	Tree killed
Hawaii	8	0	0	----	
Hebe	11	4	2	¾	
Heimbourg	10	1	2	2½	Tree killed
Helene	11	2	9	2½	
Henri Desportes	12	5	37	2	
Herard	12	2	12	1	
Heri	12	5	19	2½	
Horn's Winter	7	0	0	----	
Hospice D'Angers	11	3	4	1½	
Hourdequin	10	4	49	6¾	Tree killed
Hutin	12	5	26	3	
Idaho	5	1	1	3	Tree killed
Invalides	9	2	8	3½	Tree killed
Jaminette	11	3	9	1¼	
Jodigne (Delices)	12	3	20	7¼	Tree killed
Joigneaux	8	1	9	6	Tree killed
Joyau d'Aout	11	4	30	3	
Joyau de September	12	2	15	1½	
Juteuse de Aout	11	3	19	7	Tree killed
Kennedy	12	6	56	4	
Kieffer	8	1	2	½	
King Karl	12	3	12	1⅛	
Lady Clapp	11	3	43	3	Tree killed
La France	12	3	59	3	
Lambertye	12	2	3	1	
Lambre (Alex)	11	5	9	1	
Lameriere	11	3	9	1¾	
Lamoriciere	9	4	23	3	
La Motte	10	3	19	2½	
Laval	8	1	1	6	Tree killed
La Vientienne	12	0	0	----	
Lawrence	12	3	20	2	
Le Brun	11	3	27	4	
Leclerc (Angelique)	12	5	19	2	
Le Clerc (Van Mons)	9	1	2	1	
Le Conte	10	3	17	2	
Ledeberg	9	1	1	½	
Lelieur (Comte)	12	1	3	1	
Leopold I	10	2	16	3	Tree killed
Leroux	11	3	20	2	
Leroy	12	4	61	1½	
Levavasseur	12	3	23	3	Tree killed
Lincoln	12	2	4	¾	
Lincolner	12	3	12	2½	
Lindauer	8	1	3	6	Tree killed
Little Blanquet	11	1	1	½	
Livre	11	4	22	8	Tree killed
Long Green	10	3	38	4	
Longworth	5	0	0	----	
Louise Bonne	11	1	30	3	
Louis Pasteur	11	5	15	1¾	
Louvenjal	10	2	7	4	Tree killed
Lowe	11	3	39	5	
Lucien Chaure	8	2	23	5	Tree killed
Lucrative	12	4	8	5½	Tree killed
Lucy Duke	9	3	8	5¾	Tree killed
Luizet	8	2	14	----	Tree killed
Lyerle	9	2	12	6½	Tree killed
Madame Appert	11	5	27	1⅛	
Madame Baltet	8	2	10	4	Tree killed
Madame Caroline Airolles	12	2	24	1	

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

Variety	Age of trees	Number of years blighted	Number of infections	Diameter of largest wood killed	
				in.	
Madame Cherve	10	3	7	1	
Madame Chervet	8	1	6	5	Tree killed
Madame du Pois	11	3	5	1½	
Madame Ernest Baltet	10	3	17	5	Tree killed
Madame Favre	11	3	5	1½	
Madame Lyle Baltet	10	4	17	4½	Tree killed
Mlle, Marguerite Gaujard	9	3	9	5¼	Tree killed
Madeline	10	2	28	6	
Magnolia	9	2	4	2	
Mai	11	3	11	2½	
Malines	11	4	34	1	
Manderine	11	3	4	4	Tree killed
Marguerite	12	2	11	¾	
Maria Lesuer	11	3	12	1½	
Marie Benoist	11	4	32	3	
Marie de Barbee	12	4	22	2½	
Marie de Nouhes	11	3	22	5	Tree killed
Mas (Alex)	9	1	5	3	
Mas (du)	12	4	46	3½	
Mello	12	4	46	3½	
Menin	11	3	6	3	
Mere Perrier	7	1	1	----	
Messire	12	3	4	1	
Miller	10	4	17	2½	
Millet	11	3	19	1½	
Minster Viger	11	3	17	2½	
Monchallard	11	4	9	3½	
Montlucon	8	1	2	----	Tree killed
Monchy	12	4	9	3½	
Moulins Lille	11	4	6	¾	
Nantes	10	3	14	1½	
Napoleon I	11	4	5	1½	
Napoleon (Prince)	7	1	3	3	Tree killed
Nemours	10	1	7	7½	Tree killed
Noel	11	4	4	¾	
Notaire Lepin	12	5	32	4	
Oberdieck	10	3	19	7	Tree killed
Octave Lachambre	11	3	7	1½	
Old Home	7	0	0	0	
Olivier	7	1	1	4	Tree killed
Osmonville	10	3	11	5	Tree killed
Passe Colmar	12	5	18	3½	
Passe Crassane	8	3	8	6	Tree killed
Pathenay	12	3	11	3	
P. Barry	6	2	12	2½	Tree killed
Peche	12	5	18	1½	
Perrault	6	1	2	3	Tree killed
Pierre Curie	9	1	3	4½	Tree killed
Pierre Pepin	11	3	7	2¾	
Pitmaston	11	2	10	2½	
Poete Beranger	10	3	8	½	
Poiteau	9	2	28	6	Tree killed
Poitevin	11	4	22	2¾	
Pomologie	12	0	0	----	
Pound	10	3	51	10	Tree killed
Precoce de Angers	12	5	24	2½	
Precoce Trottier	11	4	41	6	
President Loubet	11	1	2	1½	
President Loutreul	12	6	31	2½	
Professeur Barral	8	1	3	7	Tree killed
Professeur Bozin	11	1	2	1½	
Professeur Grosdemange	11	2	11	¾	
Professor Opoix	10	4	17	5	Tree killed
Quimper	11	4	23	2½	

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

Variety	Age of trees	Number of years blighted	Number of infections	Diameter of largest wood killed	
				in.	
Rahard	8	2	22	4	Tree killed
Rance	12	4	21	1½	
Reeder	12	4	24	1½	
Reliance	10	4	26	2	
Rey	8	2	3	5	Tree killed
Rheims	12	3	16	2½	
Rheil	8	2	12	7	Tree killed
Roosevelt	8	2	5	5	Tree killed
Rosee de Juillet	12	2	4	1¾	
Rossney	8	1	15	1	
Rouennaise	10	4	12	5	Tree killed
Royal d'Hiver	9	3	14	6	Tree killed
Royal Vendee	12	3	13	3	
Saint Andre	12	0	0	---	
Saint Pere	11	3	10	1½	
Saint Vincent de Paul	8	1	9	4	Tree killed
Saladin	11	4	18	6½	Tree killed
Sanguinole (France)	11	4	10	7	Tree killed
Sanguinole (Italie)	12	3	7	3	
Santa Claus	11	4	13	3	Tree killed
Saumur	11	3	9	1½	
Sec	12	6	36	2¼	
Seckel	11	4	26	1½	
Senateur Belle	12	1	1	¾	
Seneca	11	4	30	6	Tree killed
Serrurier	11	3	9	1¾	
Sheldon	11	4	64	3	
Six	9	2	22	7½	Tree killed
Smith	8	2	4	1	
Smyth	8	3	9	1½	
Snyder	12	3	34	2½	
Soldat	11	3	14	1½	
Souvenir	9	2	30	5¼	Tree killed
Souvenir de Cronstadt	10	3	7	2½	
Souvenir de Dives	11	2	3	3	
Souvenir de Guy Bruzon	9	2	39	2	
Souvenir de Jules Guindon	10	3	8	7	Tree killed
Souvenir de Valmy	9	2	32	5½	Tree killed
Spanish	11	2	12	4	
Sterkmans	6	1	2	2¾	Tree killed
Success de la Meilleraye	11	2	2	¾	
Sudduth	12	4	24	1	
Summer Colmar	9	2	10	6½	Tree killed
Summer Doyenne	12	5	13	1¼	
Superb	7	2	2	¾	
Superfin	12	3	17	2	
Surprise	10	1	2	½	
Suzette	11	4	35	3	
Taberier de Boulogne	8	1	9	6	Tree killed
Ta Suan Li	5	1	2	½	
Tedrow Beauty	8	2	7	1½	
Theodore Williams	11	2	8	2	
Thirriott	10	3	14	4½	Tree killed
Tongres	11	5	83	4	
Totleben	12	4	28	3½	
Tougard	10	4	27	5¾	Tree killed
Trevoux	11	2	19	1	
Treyve	10	4	14	1	
Triomphe Jodoigne	8	1	4	8	Tree killed
Triomphe de Tourney	12	5	19	1½	
Triomphe Touraine	12	4	27	2½	
Tyson	11	3	18	1	
Urbaniste	8	1	3	---	Tree killed
Vaillant	12	5	50	2½	
Vaisse	12	4	47	3½	

TABLE VII (Concluded). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

Variety	Age of trees	Number of years blighted	Number of infections	Diameter of largest wood killed	
				in.	
Van Mons (Present)	11	3	17	8	Tree killed
Varenne	12	4	9	2¼	
Vauquelin	12	3	33	3½	
Vaux	10	2	27	5	Tree killed
Vermont Beauty	11	5	16	4½	
Vicar	11	4	32	8	Tree killed
Vienne	10	5	27	5¾	Tree killed
Vigneau	12	5	39	6	Tree killed
Vilmorin	12	3	4	1	
Virginie Baltet	9	2	14	5¼	Tree killed
Vital	8	1	1	5	Tree killed
Warner	10	3	109	7	
Weidner	10	3	29	10	Tree killed
White Doyenne	12	5	12	1½	
Williams de Hiver	12	4	23	3½	
Windsor	8	3	12	2½	
Winter Bartlett	12	6	94	4	
Winter Nelis	11	4	14	3	
Worden Seckel	10	4	50	2¾	
Ya Kuang Li	7	2	3	½	

PART II. CHARACTERISTICS OF PEAR SPECIES AND PEAR STOCKS

DISCUSSION OF THE MOST IMPORTANT SPECIES

PYRUS COMMUNIS

Pyrus communis, commonly known as the European or cultivated pear, includes the leading varieties cultivated in America and also the French seedlings used as stocks. It is a native of Europe and southwestern Asia and is most abundant in Austria. It has been widely cultivated throughout Europe for centuries and in many parts of the United States for the past two hundred years. About the middle of the last century it received a great deal of attention from American pomologists, special consideration being given to the introduction and testing of new European varieties. The finest of these varieties are superior in quality to those of any other species.

Description. This species is so well known and so distinct from other species of pears that a complete description is unnecessary here. Attention need be called only to the most salient characteristics. The tree is a vigorous, upright grower with a central leader and a coneshaped top. It possesses many stout, medium sized thorns. The bark is usually brown or purplish-brown in color, the shoots being pubescent when young but usually becoming glabrous with advanced growth. This species is readily distinguished from all others by its small or medium sized leaves, which are oval or oblong-ovate, with short rounded or acute apex, and rounded base; the margins are either entire or possess small crenate-serrate teeth. The white, medium sized flowers have rounded petals, possess eighteen to twenty stamens and always five pistils, and are borne in small compact clusters. The fruit of the wild type is approximately an inch in diameter, usually pyriform, green or greenish-yellow in color, with a persistent calyx, white, soft, juicy flesh, and a five celled core.

Climatic requirements. *P. communis* is admirably adapted to the milder portions of the temperature zone. In America it reaches its greatest perfection in the northern states east of and adjacent to the Great Lakes, and on the Pacific Coast. It is not hardy in the extreme north or in the upper Mississippi Valley. While the trees will grow in the southern states, they are unproductive and are speedily destroyed by the ravages of fire blight. Bartlett is the most cosmopolitan of all the *P. communis* varieties and is successfully grown over a greater range of territory than any of the others.

Soil adaptation. This species will grow on a great variety of soils, ranging from sandy loams to heavy clays and adobes. It reaches its greatest perfection, however, on the heavier types—the fertile silty and heavy clay loams and certain types of clays and adobes. Bartlett and Howell can be successfully grown on a far greater variety of soils than Anjou, Bosc and Comice and some of the other varieties. In Southern Oregon Bartlett, Bosc, Howell, and Winter Nelis are very successfully grown on heavy adobe soils which are unsuited to most of the other types of fruit. On fertile adobe soils these varieties are productive and develop flavor and keeping qualities seldom attained on any other type of land.

While this species thrives best on well drained soils, it will tolerate wet soils better than any of the other common fruit trees; much better, also, than the Japan pear stock or any other species of pears with the possible exception of *P. calleryana* and *P. betulaefolia.* This is particularly true in the mild winter climate of the Pacific Coast, where such varieties as Bartlett and Winter Nelis on French pear stock are sometimes grown on soils which are so wet during part of the winter that practically all other fruit trees would speedily perish. Naturally such soils do not produce as good results as those which are well drained, but when planted to the varieties mentioned above the returns are far more satisfactory than would be expected by one familiar with the culture of other tree fruits. In colder climates trees on soils of this character would undoubtedly survive only a short time.

While the French stock will withstand the effects of a limited amount of alkali, it is readily killed by a quantity which *P. betulaefolia* will endure with impunity.

Value as a rootstock. Until comparatively recent years the French stock was the only species of Pyrus used as a rootstock for American pears, and at this time it is more extensively used than any other. It makes a strong, smooth union with all the European varieties and the trees are vigorous and long lived. This stock is remarkably well adapted to the climatic and soil conditions in the leading pear districts of the Pacific Coast. In the portions of this territory where root blight is not troublesome this stock should be given preference over all others at the present time. In those regions, however, where root blight is very troublesome a large proportion of the French seedlings now available will not prove satisfactory. In such regions it will undoubtedly prove safer to use a more blight-resistant stock, such as *P. calleryana.*

In the northern states and particularly in regions where root blight is not an important factor this species is undoubtedly the safest one to use at the present time. It will endure lower temperatures than the Japanese pear, hence is preferable to that stock in the colder portions of America. In the warmer portions of the South the French stock is far more susceptible to blight and certain root rots than the Japanese stock, and there it has been largely replaced by the latter.

As shown in Table V, a few of our *P. communis* varieties, notably Old Home, Farmingdale and Longworth, have manifested a high degree of resistance to blight. The fruit of these is of little importance, but the trees are of great value as blight-resistant trunk and body stocks for our better commercial varieties. Old Home is particularly promising for this purpose because of its hardiness, extreme vigor, resistance to blight, and perfectly formed framework. These varieties of *P. communis* when used as trunk and framework stocks suffer less from winter injury in the wet winter climate of Southern Oregon than those of certain other species, notably *P. ussuriensis.*

Pear Blight. The most serious objection to *P. communis* is its extreme susceptibility to pear blight. It is far more susceptible to this disease than any other important species. In America the loss sustained by *P. communis* varieties from blight has undoubtedly been greater than that of any species of fruit from any other disease. Furthermore, this disease has unquestionably been responsible for greater losses in American pears than all

Fig. 23. Leaf of Japanese Sand Pear *(P. serotina)*.

other pear diseases combined, and it has been the greatest hindrance to the development of the pear industry in this country.

The inoculation results obtained with this species have been presented in Tables I, II, V, VI, and VII of this bulletin. All of the French seedlings inoculated have proved to be susceptible in the tips; 74.1 percent of the trunk inoculations developed infections which destroyed two-thirds or more of the tree, and 43.8 percent of the root inoculations were successful. The percentage of root infections, therefore, is nearly twice as great as that in any of the other species and almost five times as great as that in *P. calleryana.* A far greater percentage of the cultivated varieties of this species have proved susceptible than in the varieties of the other species.

A small percentage of *P. communis* seedlings, however, were immune in the trunks and roots, and if these can be propagated true to type they will be of great value. Seeds from each of these will be planted separately to determine whether any of the trees will transmit to a high percentage of their seedlings the factor of resistance to blight. If this should prove to be the case such types will thereafter be used as mother trees to supply the desired seeds. These trees can also be propagated true to type from root cuttings, and experiments are now in progress to determine whether this can be successfully done on a commercial scale. If so, one of our most perplexing rootstock problems will have been solved.

Leaf blight. The French pear seedlings are very susceptible to leaf blight *(Fabraea maculata).* The effects of this disease are particularly disastrous to these seedlings in the humid summer climate of the eastern states. In those regions this fungus attacks the leaves and when prevalent it stunts the growth of the trees and often defoliates them long before the end of the growing season, thus materially shortening the budding season with this stock, and in some years the growth is so impaired that no budding can be done. In contrast to this, most of the Chinese species are remarkably resistant to leaf blight and have a long budding season.

Mushroom Root Rot. The French pear seedlings are remarkably resistant to Mushroom Root Rot *(Armillaria mellea),* a disease which is found in many of the fruit districts of the Pacific Coast. This is a malady which often attacks and in numerous cases destroys the roots of a great many varieties of our common fruit trees. By reason of possessing such a marked degree of resistance to this disease, the French pear virtually stands in a class by itself. While trees of this species affected by Mushroom Root Rot have been found, they are extremely rare and the injury seldom proves serious. This is indeed fortunate, since the disease is difficult to combat when susceptible trees become infected. The high degree of resistance shown by the French seedlings stands out in sharp contrast to the marked susceptibility of the Japanese pear seedlings to this disease.

Pear Woolly Aphis. Unfortunately, the French seedlings are highly susceptible to the Pear Woolly Aphis *(Eriosoma pyricola).* This insect is abundant in most of the pear districts of the Pacific Coast. It prefers the roots of the *P. communis* seedlings and does the greatest damage in nurseries and young orchards. It saps the vitality of the young trees, thus seriously stunting them, and in rare cases, during very dry seasons, the trees are killed. Woolly aphis exacts a heavy toll from the nurseryman as it often damages a high percentage of trees on this stock to an extent which precludes their sale.

Fig. 24. Fruit and leaves of *P. koehnei*. This species appears very promising as a stock for very warm climates.

This insect has been responsible, in a large measure, for the displacement of the French stock in nurseries on the Pacific Coast by the more resistant Japanese stock.

To summarize: the French stock has a number of valuable characteristics; it makes a fine stock for American pears and the union with them is excellent; it will endure wet, shallow, and very heavy soils better than any other pear stock except possibly *P. calleryana;* and it is highly resistant to Mushroom Root Rot. Its objectionable characteristics are susceptibility to pear blight, leaf blight, and Pear Woolly Aphis.

Pear breeding. In the production of varieties of superior quality *Pyrus communis* is the most important of all species of pears. According to American and European standards the finest *P. communis* varieties are superior to those of any other species. They possess a combination of admirable qualities, including size, form, juiciness, tenderness of flesh, and delicacy of flavor, found in no other species. These characteristics must enter into any new varieties produced for American and European consumption; hence in breeding work this species must be used as one of the parents. In the production of new varieties we must also strive for certain characteristics not now found in our best pears, and the most vital of these is resistance to blight. Among cultivated pears this characteristic is most pronounced in certain varieties of *P. ussuriensis.* Judging from all available evidence it seems probable that we are most likely to develop the desired new pears from hybrids of the best varieties of *P. communis* and *P. ussuriensis.* The best *P. communis* varieties for this purpose, which have already been tested, are Bartlett, Anjou, Bosc, Comice, and Winter Nelis.

PYRUS CALLERYANA

Pyrus calleryana is a native of central China, being especially abundant in the Yangtze Kiang River Valley. It is widely distributed from near sea level in eastern China to more than a thousand miles inland and to an elevation of at least five thousand feet. The most northern limits of the species in China are not known. In 1919 the writer found large trees growing vigorously in southern Shantung Province, considerably further north than any point from which it had formerly been reported, and this is probably near its northern limit. Its southern limit has not been determined. It has been collected, however, in several other provinces at least two hundred miles south of the Yangtze river.

A sub-species of *P. calleryana,* known as *Pyrus calleryana-dimorphophylla,* has been found by Japanese botanists and also by the writer in various places in the Ise Province of southern Japan. This sub-species produces two types; one, which is rare, with leaves similar to the Chinese form, and another with long, narrow leaves. The fruit is identical with that of *P. calleryana.* The trees have not proved as vigorous or as resistant to blight as the typical species found in China.

The species is characterized as follows: trees medium to large in size and vigorous; the bark on younger wood smooth and glossy, but on trunk and older wood more or less furrowed, seldom, however, with transverse checks such as are found in *Pyrus betulaefolia.* It is readily distinguished from all other species by its leaves, which are medium to large in size, ovate, with a green, glossy surface and rounded or crenate marginal teeth. On young seedlings the leaves are usually ovate-lanceolate, slightly folded upward and

with margins crimped. The trees bloom very early, usually beginning one day later than the wild type of *Pyrus ussuriensis*. The flowers are borne in great abundance, laterally, on the previous year's wood and on spurs of older wood. With the exception of *Pyrus betulaefolia* it probably produces more blossoms than any other species of Pyrus. The blossoms are small, from

Fig. 25. Showing blight resistant stock properly top-worked with commercial variety. The buds of the commercial variety were inserted at points indicated by the white bands on the young branches.

two-thirds to three-fourths of an inch across, petals white and round, borne on small short claws. The number of stamens varies from eighteen to twenty, with beautiful dark red anthers. It has two and rarely three pistils. The fruit is borne in clusters, is small—about one-third of an inch in diameter—round and entirely covered with russet, and the calyx is deciduous; it possesses a thin layer of greenish flesh, and an extremely heavy, thick continuous

layer of large grit or stone cells around the core; usually two and occasionally three celled, with two very small, dark brown or black seeds in each cell.

Introduction into the United States. *Pyrus calleryana,* so far as can be determined, has had a very brief history in the United States. The earliest introductions were those made in 1908 by Mr. E. H. Wilson, of the Arnold Arboretum. Mr. Wilson collected the seed in the western part of the Hupeh Province, in China, at an elevation of four to five thousand feet. This type has proved hardy near Boston, Massachusetts.

In 1917 the writer and the late F. N. Meyer of the U. S. Department of Agriculture collected a large quantity of seed in several places in central Hupeh Province near Kingmen, and in the mountains west of Ichang, China. From these seeds thousands of plants were grown, many of which have been used as rootstocks, and others have been thoroughly tested for blight resistance. In 1919 the writer collected additional seed and studied the species in southern Shantung Province, China.

Blight resistance. The results of the work on blight resistance in this species are presented in Table II of this Bulletin. These results show that a higher percentage of the roots and trunks of *P. calleryana* are resistant to blight than in any other important species. Only 2.5 percent of the trees inoculated in the trunks blighted into the roots and only 9.1 percent of the root inoculations were successful. This is fortunate, indeed, since this species also possesses other characteristics which make it very valuable as a stock.

Economic importance. The fruit of *P. calleryana* is of no value, as it is extremely small, contains little flesh, is very gritty and possesses a wretched flavor.

As a stock. *P. calleryana* promises to be a valuable stock for American pears.[6] A large number of seedlings were grafted with our leading commercial varieties in the spring of 1919. These have been planted in a stock test orchard and are being carefully studied. The trees on this stock have made a splendid growth, surpassing in vigor and uniformity the same varieties on the standard French seedlings and those on *P. ussuriensis,* as well as on all the other stocks planted at the same time and in adjacent rows.

This stock has made a perfect union with Bartlett and Anjou, stock and scion being identical in size, and without the slightest enlargement at the union. The Bosc, Howell and Winter Nelis have made a splendid growth on this stock and the union is strong and apparently congenial. Part of the trees of each of these three varieties, however, are slightly larger in diameter than the stock below the union. If the difference in size does not become greater than it is at present it will not prove detrimental. These trees were grafted from twelve to twenty-four inches above the ground where the unions can be easily studied. It is quite probable, judging from other evidence which we have, that no differences in size of stock and scion would exist if these trees had been grafted at or below the surface of the ground. The Comice trees have also made a fine growth on this stock, but this variety is considerably larger than the stock. Comice shows this characteristic on any stock when grafted above the ground, but not when worked at or below the ground. Some of these Comice trees top-worked on other French varieties above ground, and which have far outgrown the stock, are among the most productive old trees of this variety in Oregon. Until we have further evi-

Fig. 26. Typical tree of Old Home showing vigor, well shaped framework, and freedom from blight.

dence, we recommend grafting the Comice at the surface of the ground when it is propagated on *P. calleryana.*

For Southern Oregon our advice is to use *P. calleryana,* or other seedlings, only for the root system of our pear trees and that certain resistant body stocks be budded or grafted on to this at or below the surface of the ground. For such trunk stocks there are several varieties and types which appear promising at this time. Among these are Old Home, Variolosa, Farmingdale, and probably others. In one of our stock orchards Old Home has been budded on *P. calleryana* and other stocks in this manner. The trees have made an excellent growth and the union appears to be perfect. These trees are very uniform and are larger and more vigorous than Old Home on French or any other rootstocks. These Old Home trees are now three years old and will be top-worked with commercial varieties.

It is quite possible that some of the selected and tested blight resistant strains of *P. calleryana* which produce a very vigorous, upright growth of desirable form, may be used for the trunk and frame work. These should be propagated only by budding or grafting to keep them true to type.

One of the advantages of *P. calleryana* is that the seedlings cannot be confused with those of any other species. The leaves are so characteristic and so distinct from those of all other pear stocks that any nurseryman can readily identify this species. Furthermore, there should be little difficulty in getting reliable seed, for it is only about one-fourth as large as that of French, Japanese, and *P. ussuriensis* seed, and can be distinguished at a glance from these species. Unfortunately the seed of *P. calleryana* is very similar to that of *P. betulaefolia;* in fact, it is very difficult to distinguish between them. Furthermore, there is danger of getting a mixture of the two, since both species are common in central China, and the exterior of the fruit as well as the seed of both, is similar in appearance. The appearance of the trees of these two species, however, is so distinct that any collector can readily distinguish them. While the exterior of the fruit of these two species is similar, the interior is very distinct. *P. calleryana* contains an abundance of large and very conspicuous grit cells, while *P. betulaefolia* usually contains none. In the nursery the *P. calleryana* seedlings, with their glossy bark and green, glossy, ovate leaves with crenate margins, can be distinguished at a glance from the light gray, fuzzy shoots and light fuzzy, lanceolate, coarsely serrated leaves of *P. betulaefolia.* Fortunately, the College of Agriculture, at Nanking University, Nanking, China, is making a specialty of collecting and supplying American nurserymen with reliable seed of *P. calleryana. P. calleryana* seed germinates quickly and should not be stratified for more than one month before planting.

Types of root system. The root systems of the various seedlings of this species show marked variation in habit of growth. Part of the seedlings develop a highly desirable, well branched root system even without transplanting. Other trees have a tendency to produce a very long tap-root with few side or branch roots. On deep, mellow soils some of these trees have produced a tap-root four to five feet long with few or no side roots. This has occurred only in trees which had not been transplanted. This habit must be and can be overcome. We have found that all of the trees develop well branched root systems if the seedlings are dug when one year old, the tap-root cut back to eight or ten inches, and the tree transplanted. Fortunately, this is the practice usually followed by nurserymen with pear stocks. With *P. calleryana* such

transplanting is absolutely necessary for best results. In ordering trees on this stock the grower should insist on getting well branched root systems.

Resistance to Woolly Aphis. One of the most important characteristics of *P. calleryana* is its high degree of resistance to the Pear Woolly

Fig. 27. Four-year-old seedling of cultivated *P. ussuriensis*.

Aphis. This insect is a serious pest on French pear stocks on the Pacific Coast. Among the many seedlings of the French pear stock of various ages at this Station it is difficult, during late summer and early fall, to find any which are free from this aphis. Very often the French roots are literally

covered with white masses of it. Under identical conditions and often in adjoining rows, the roots of *P. calleryana* seedlings are entirely free from this insect. In thousands of seedlings which have been dug at this Station these aphids are rarely found on *P. calleryana* and in no case has there been a sufficient number on the roots to produce the slightest injury. In this respect *P. calleryana* appears to be superior to all other species in our collection.

Soil adaptations. Judging from the observations made in the Orient, *P. calleryana* is adapted to a great variety of soil conditions. The writer has seen it growing there in soils varying from granite and coarse sands to very heavy clay, and it is apparently at home on all types. It appears to be able to withstand equally great variation in soil moisture conditions. It was often observed growing on very dry mountainsides, on various valley lands, along streams, and in wet, poorly drained swamps. The writer observed and photographed one tree actually growing in a pond and the species is very common along the margins of swamps. Naturally, the largest and most vigorous trees were on rich, deep, moist, well drained valley soils. While it grows on cliffs and mountainsides covered with a very thin layer of soil, this is in a region where the summer rainfall is heavy and even then the trees are much smaller than those on deeper and more fertile soils.

When used as a rootstock it is probable that this species will grow successfully on as great variety of soils as the very cosmopolitan French stock.

Trees propagated on this stock have been planted on various soils at the Experiment Station and other places in this Valley, ranging from clay loams to heavy adobes. Up to the present time these young trees have made a very satisfactory growth. One young orchard of this species on a dry hillside has made a far more satisfactory growth than cultivated *P. ussuriensis* growing under the same conditions.

Climatic adaptations. Since this species comes from central China where the summers are hot and humid and the winters very mild, it is probable that it will not endure the low temperature in most of our northern states. One of the surprising things about the species, however, is that some forms are hardy at Boston, Massachusetts. These forms were grown from seed collected at high altitudes in China. All of the forms of this species have proved perfectly hardy at this Experiment Station, where the temperature has gone below zero only one time. In the unprecedented freeze of December, 1919, when the temperature went to ten degrees below zero, none of the types from central China were injured. Following this freeze the cambium of the branches and trunk was dark brown or black, and remained so until the following spring, indicating serious injury. However, in the early spring they began growing at the normal time and made a very vigorous growth without showing the slightest effect of the freeze. The roots showed no discoloration at any time. Nevertheless, this stock is not recommended for cold climates. Until we have further evidence, it should not be used where the temperature goes lower than ten degrees below zero, and then only for rootstocks. It appears to be particularly well adapted to the mild climate of Southern Oregon and California.

Judging from conditions under which it thrives in its native habitat, this species should be well adapted to the southern states and especially the Gulf Coast states, because the summer climatic conditions there are similar to those of central China. The few plantings made there have been very suc-

Fig. 28. Showing Anjou graft on cultivated *P. ussuriensis*. Note the perfect union at point on trunk indicated by arrow.

cessful. Trees sent to Florida and Mississippi have made a clean and vigorous growth and appear to be perfectly at home.

This species is able to endure drought much better than *P. ussuriensis*. Growing side by side with the latter on dry sandy soil underlaid with gravel beds, the leaves have never shown the slightest sign of sunburn or wilting, while leaves of *P. ussuriensis* have been badly sunburned and in extreme cases have dropped off. Naturally, under such dry conditions the trees are not as vigorous as on deep, moist soils.

It is probable that trees grown from seeds collected in the warm regions within the southern limits of the species and at low altitudes will not prove as hardy as trees from seed collected in the extreme northern limits and the high mountains of central China. Therefore, considerable care should be exercised in purchasing or collecting seeds in China for planting in the United States.

Since this species comes from a region with a comparatively light rainfall during the winter months it will probably prove hardier in the drier parts of this country than in those with a heavy winter rainfall. It will also undoubtedly make a more satisfactory growth in regions with a heavy summer rainfall than it will without irrigation in the drier and hotter portions of the country. Seedlings of this species have proved satisfactory near Washington, D. C.[1] There it is a clean, lusty grower, holding its leaves until late in the fall, and has proved resistant to leaf blight.

In Southern Oregon young seedlings of this species are remarkable for holding their foliage until early winter and often until mid-winter. This is especially true of the young seedlings from one to three years of age. As they grow older they become better adapted to conditions and drop their leaves at a more seasonable time. With the trees in full leaf in November and December, however, they appear to suffer very little from the heavy frosts. This characteristic of retaining their leaves until late in the season is probably due to the long growing season under which this species developed in central China.

P. calleryana cannot be considered one of the more promising species for the pear breeder; certainly not for the breeder primarily interested in developing varieties with large fruit of fine flavor. The fruits of this species are extremely small, filled with grit cells and utterly worthless for eating. *P. calleryana* may prove of value in breeding and developing better trunk stocks. It is possible that some of the hybrids between this species and our most resistant American varieties will give us stocks for the trunk and framework which will be even better than the pure *P. calleryana*.

PYRUS USSURIENSIS

Pyrus ussuriensis is a native of extreme northern China, Manchuria, northern Korea and southeastern Siberia. There it is abundant, especially on the rich, valley soils. The trees are moderately vigorous, long lived, and very old specimens attain great size. The writer observed some of these trees in extreme northeastern China which were from two to three feet in diameter and from fifty to seventy-five feet high. Wherever tested in America the wild type of this species has proved a very slow grower. The wood is very heavy and hard, and when young the bark is smooth and of a distinctive greenish-yellow color. The bark on the older trunks becomes dark in color and deeply and characteristically furrowed and checked.

The leaves are glossy, medium to large, broadly ovate in the wild type, varying from ovate to oblong-ovate in the cultivated varieties, abruptly pointed and often twisted; and on most of the young seedlings of the cultivated types the leaves are folded upwards and with the edges usually waved or crimped. The wild type and some of the cultivated varieties—particularly Man Yuan Hsiang—often produce a rosette of leaves at the end of the

Fig. 29. Fruit of Ba Li Hsiang, an immune variety of *P. ussuriensis*. This has given a higher percentage of immune seedlings than any other variety. Fruit natural size.

branches. The margins of the leaves are always setose-serrate, with the bristles longer than those of any other species of Pyrus.

The wild forms and some cultivated varieties bloom earlier than any other species, preceding those of our American varieties by ten days to two weeks. The blossom buds are a beautiful reddish pink in color. The flowers are larger than those of any other pear and vary in color from pink to white in different varieties. The petals are very large, obovate, slightly clawed; sta-

mens vary from eighteen to twenty and bear beautiful, large, red anthers. There are always five pistils and this characteristic distinguishes the species from all the other distinct species of northern China.

The fruit of the wild type is from three-fourths to one inch in diameter, round or slightly flattened, greenish-yellow in color, with often a red cheek, a persistent, spreading or erect calyx, and a very short, thick stem. In the wild forms the flesh is hard, but becomes soft when fully ripe, with a very thick, continuous layer of stone cells around the core. Core, five celled with two large, dark brown or black seeds in each cell. The fruit of the cultivated varieties varies from slightly oblate to obovate in form, and some varieties are soft fleshed, juicy and practically free from grit cells. The flavor varies from acid in the wild forms to mild subacid in many of the cultivated varieties. This flavor is agreeable, sprightly and quite distinct from the insipid sand pears of central China and Japan.

The tree of the wild type is very hardy, and is the only species of Pyrus known in Siberia and northern Manchuria. It has been known to endure a temperature of forty degrees below zero and withstands the severe climate of St. Petersburg, Russia. In the United States certain seedlings of this species have proved hardy at Brookings, South Dakota, and in northern Iowa.

History in the United States. There is no record of the first introduction of this species into the United States. The oldest tree in this country of which the writer has any knowledge is now growing on the Patten Experimental Farm at Charles City, Iowa. This tree was obtained by Mr. Charles Patten[4] from O. H. Bardhall at Grundy Center, Iowa, in the spring of 1884. Mr. Bardhall obtained his tree in 1880 from the nursery belonging to John Collins & Son at Morristown, New Jersey. There is no record of the source from which John Collins & Son obtained this type. It was advertised as a Chinese pear, with fruit as large as that of the Flemish Beauty, but when the variety came into bearing it produced small, green, hard, sour pears about one inch in diameter. It is probable that Mr. Collins obtained this pear from some sea captain, in the form of seed collected in China. Mr. Collins knew many of the captains of ships that came to Philadelphia and they often presented him with plants and seeds from foreign countries. It is quite probable that the seed originally came from a cultivated variety producing large pears, and that the seedlings reverted to the wild type which bears small, inferior fruit.

Mr. Patten was attracted to this tree because of its great hardiness, as it was not injured by the extremely cold winter of 1883-84 in northern Iowa. He published several articles regarding this type and used it extensively in his breeding work. However, it was always listed and described as a Chinese Sand Pear and designated as *Pyrus sinensis*. In the fall of 1916 the present writer identified it as *Pyrus ussuriensis*. While not immune, it is highly resistant to blight.

In the fall of 1907 Mr. Frank N. Meyer, explorer for the United States Department of Agriculture, collected seeds of this species in extreme northern China,[3] and in eastern Siberia. These seeds were sent to the Department of Agriculture and seedlings were later distributed to several Experiment Stations. The writer obtained propagating wood from one of these seedlings and in our inoculation experiments it has proved highly resistant, although not immune, to blight.

In 1917 the writer found this species in several places in central Manchuria and extreme northeastern China. A considerable quantity of seed and scionwood of some of the wild and cultivated types was obtained, and from this material many trees were grown and tested. Many of the seedlings of the wild type and the cultivated varieties proved highly resistant, and some of them immune.

In 1919 the writer again visited these countries and obtained a large quantity of seeds of the wild and cultivated types, and scionwood from nearly all of the known cultivated varieties of this species. These have been thor-

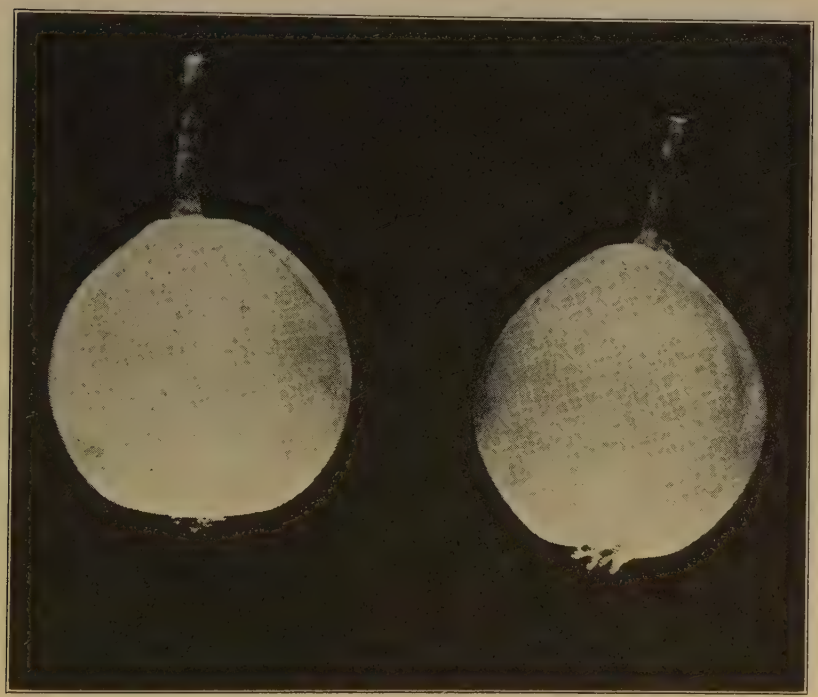

Fig. 30. Fruit of Hsiang Sui Li. (Natural size.) This is one of the two best flavored varieties of *P. ussuriensis* as grown in Southern Oregon. It has proved practically immune to Pear Blight. Flesh soft, juicy, subacid. Desirable for breeding work.

oughly tested for blight resistance at this Station, where the wild type proved more resistant than any other species, some cultivated varieties proved immune, and the seedlings of these varieties ranked second only to those of *P. calleryana.* The seedlings of one variety proved even more resistant than *P. calleryana.*

Climatic adaptations. *Pyrus ussuriensis* is a native of the cold north, ranging from extreme northeastern China, through Manchuria, into eastern Siberia. In that region the summers are comparatively short, with most of the annual rainfall coming during the months of May, June, and July. The remainder of the year is comparatively dry. The winters are dry and very

cold, the low temperatures ranging from ten degrees below zero in northern China, to forty degrees or more below in eastern Siberia.

This species originated in a climate with cold, dry winters and it will endure much lower temperatures in a dry than in a wet winter climate. Young trees of some of these varieties which endure twenty degrees below in the dry winter climate of Manchuria showed heavy trunk injury at two degrees above zero in the damp winter climate of Southern Oregon. Some of the wild types of *P. ussuriensis* have endured a temperature of forty below zero in northern Iowa and in South Dakota. We are finding great variation within this species; some varieties have shown no injury whatever, while in other varieties all the bark on the trunks has been killed.

P. ussuriensis will probably prove of greatest value in those portions of the United States having comparatively short, cool, moist summers and dry, cold winters. It is evident that the wild forms are not well adapted to the hot, dry summer climate of Southern Oregon. Here this type suffers from drought unless irrigated, and during the very hottest weather there is considerable sunburn injury to the leaves. Some of the cultivated forms are giving excellent results.

The young seedlings of Guar Li,* a cultivated variety of this species, have made a very satisfactory growth and seem to be well adapted to the climatic and soil conditions prevailing near Washington, D. C.

Soil adaptation. In the Orient this species is usually found growing on the deep, rich, silty and sandy loam soils in the valleys and in well protected mountain coves. The best wild groves observed by the writer were those on the silty loam soils in the Hsing Lung Shan Valley at an altitude of twenty-four hundred feet, and about one hundred miles northeast of Peking, China. In that Valley the trees attain enormous size and great age. These soils are well supplied with moisture during the summer months, but are quite dry the remainder of the year. It is probable that the species will not prove satisfactory on poorly drained soils, especially on those that are wet during the winter months, as such conditions are just the opposite of those found in its native home. The trees are sensitive to alkali and become chlorotic on soils containing excessive amounts of lime.

The trees are deep rooted, hence shallow soils underlaid with hardpan will probably prove unsuitable. Sufficient evidence has not yet been obtained to determine this, as the history of the species in this country, with the exception of a few trees, is very brief.

A question of great importance is whether this species will be adapted to the very heavy clay and adobe soils found in certain pear districts of the west. Young trees on this stock have made satisfactory growth on such soil at this Station. These very probably will not prove as long lived or as satisfactory on such heavy soils as on deep, mellow soils.

Since this species has been grown in such a limited way in the United States little is known regarding its resistance or susceptibility to the various fungous diseases attacking the pear in this country. Owing to our dry spring and summer climate, there is far less trouble from fungous diseases at this Station than in the humid eastern part of the United States. Here many of the leaf fungi are unknown. For this rea-

*See Journal of Heredity for January, 1920, page 29, where this variety is designated as Kuan Li.

son it is not a satisfactory climate for determining the resistance of the various species to the usual fungous troubles of the pear. Up to the present time these trees have been practically free from leaf spots, various cankers, and scab on the fruit. Seedlings of Guar Li, a variety of this species, proved remarkably free from pear leaf spot near Washington, D. C.

One of the most troublesome fungous diseases affecting rootstocks on the Pacific Coast is the Mushroom Root Rot. Growers in California have reported three cases of this disease on young seedlings of *P. ussuriensis*. None have been observed in our collection, although this observation

Fig. 31. Fruit of Chien Pa, a cultivated variety of *P. ussuriensis*. This variety has proved immune to Pear Blight. Fruit of good quality in Manchuria. Has not fruited in America.

is of little value, since the soil at this Station is free from this fungous trouble. Trees of this and the other promising species of Pyrus have been planted on a plot of soil in the Hood River Valley, Oregon, known to be infected with this disease; hence the evidence will ultimately be obtained on the resistance or susceptibility in these various species.

The Pear Woolly Aphis is a serious menace to the roots of young pear trees in many orchards on the Pacific Coast. It is especially troublesome on the French stock. This insect, up to the present time, has not proved serious on *P. ussuriensis*. While it is found on these seedlings, it is seldom present in sufficient numbers to cause injury. Among hundreds of trees which have

been dug at this Station only three have been found which were heavily infested.

As a rootstock. Our inoculation work has demonstrated that the wild type of *P. ussuriensis,* and also the Ba Li Hsiang—a cultivated variety of this species—produced a higher percentage of seedlings with roots immune to blight than any of the other species tested. For this reason, this species, and particularly this variety, is being thoroughly tested as a rootstock for our American pears. This work has been in progress for six years, hence the results obtained apply only to young trees.

The results have already demonstrated that the seedlings of the wild type of this species make too slow growth to be satisfactory as stocks for our American varieties. These varieties outgrow the wild stock, and the trunk above the union soon becomes very much larger than the stock. The difference in size eventually becomes so great that the tree breaks off at the union. Therefore, the wild type should not be used as a stock under any conditions, and in future importations of seed every effort should be made to prevent collectors in the Orient from supplying seed of the wild trees. Unfortunately, some of the dealers in the Orient have supplied American nurserymen with this seed. It is practically impossible to distinguish the seed of the wild from that of the cultivated type.

With few exceptions the cultivated varieties of *P. ussuriensis* are far more vigorous than the wild form of this species. This is a natural result since the orchardist in China has selected the most vigorous and productive forms for propagation and cultivation. Most of the seedlings of certain cultivated varieties are very vigorous growers, equaling in this respect the French seedlings which have heretofore been the chief pear stock for American varieties. This is particularly true of the seedlings of Ba Li Hsiang, Guar Li, Hung Guar, and Man Yuan Hsiang. Part of the seedlings of these and of all other varieties, however, are slow growers, apparently reverting to the wild ancestor. These slow growing trees should be discarded by the nurseryman. The best plan is for the orchardist to purchase only the largest sizes of one-year-old trees, not less than four feet and preferably five to six feet high. By doing this he avoids, in a large measure, trees with slow growing root systems. The seedlings of one variety, Ta Suan, have proved especially unsatisfactory, with a very high percentage of dwarf trees. This was unexpected, as the parent variety is one of the most vigorous growers in this species. It is quite possible that the poor growth of these particular seedlings may be due to the seeds having been fertilized with pollen from a very slow growing variety. The cause will be determined by work now in progress.

One variety—the Ba Li Hsiang—has produced seedlings which have proved so superior to those of other varieties that it deserves special consideration. We have already shown in Table III that Ba Li Hsiang is immune to blight. Also that in the seedlings of this variety none of the trunk infections extended into the roots; and further, that only 3.9 percent of the seedlings inoculated in the roots blighted. It has also produced as large a percentage of vigorous seedlings as any *P. ussuriensis* variety in our collection. This is quite remarkable since Ba Li Hsiang is one of the slowest growers of all cultivated varieties of *P. ussuriensis.* Hence the vigor of these seedlings may be due to the male parent which furnished the pollen that fertilized these seeds. Pollination work will be undertaken at once to ascertain what male parents will produce the most vigorous and resistant seedlings with this

variety. Since the writer possesses the few other varieties that were present in the orchard in China where he obtained this seed, it will doubtless prove a simple matter to determine the variety that fertilized the seed of Ba Li Hsiang which has given us these valuable seedlings.

Ba Li Hsiang possesses other desirable characteristics as a seed parent. It comes into bearing at a remarkably early age and is one of the most productive varieties in our collection. The small fruit is borne in numerous clusters with from two to six pears in a cluster. Consequently each tree produces a large amount of seed.

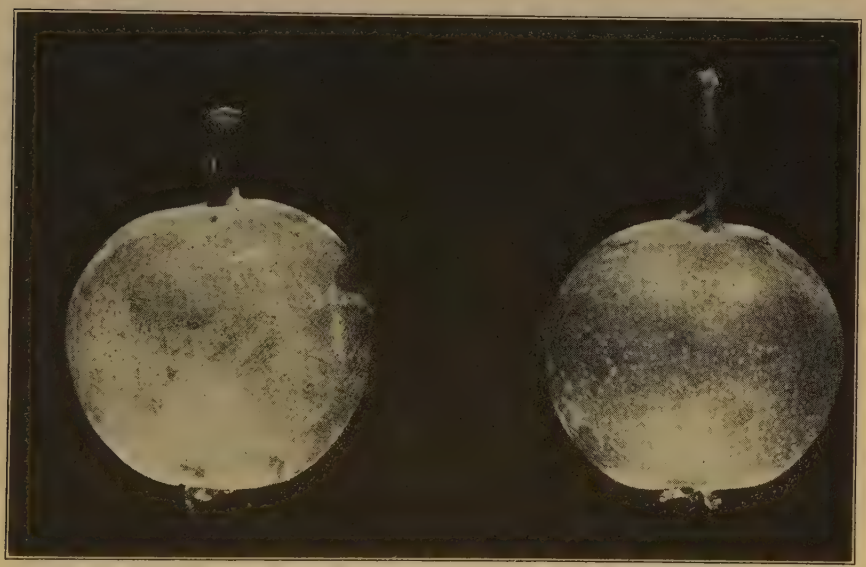

Fig. 32. Fruit of Huang Hsiang Sui, a variety of *P. ussuriensis*. Tree has proved immune to Pear Blight. Fruit of poor quality.

Unfortunately, this variety is very rare in China. The writer found it in only one small, inaccessible mountain valley in extreme northeastern China, within a mile of the Great Wall. Even there it was grown in only a limited way, due probably to its poor quality. Hence the amount of seed of this variety that China could supply at present is insignificant and practically impossible to obtain. It will be necessary for America to produce its own seed of this variety, and seed orchards should be established at once in this country.

The results in Table II show that a few other varieties of *P. ussuriensis* produced a high percentage of seedlings sufficiently resistant to blight. Of these the following are worthy of consideration: Chiu Suan, Guar Li, Hung Guar, Hu Pi Hsiang, Man Yuan Hsiang, and Ta Tze Hsiang. Of these Chiu Suan has proved productive, although not as resistant as Ba Li Hsiang. Man Yuan Hsiang has proved unproductive at this Station. The other varieties have not yet fruited here, hence we know nothing regarding their productiveness in this country. Unless they are productive they will be of little value

as seed parents. Ta Tze Hsiang produces a high percentage of dwarf seedlings.

The seedlings of the other varieties, viz: An Li, Chieh Li, Chien Pa, Chiu Tze, Hua Kai and Tzu Ma, proved too susceptible to blight to be of value. However, this result may have been due in a measure to the influence of the unknown pollen parent; particularly so in the case of Chieh Li and Chien Pa, for these two varieties have been very resistant. These varieties, however, cannot be recommended as seed parents until it is shown that they are valuable when pollinated with certain varieties.

It is particularly unfortunate that such a large percentage of the seedlings of Chiu Tze have proved susceptible to blight. This variety is extensively grown in a very accessible region of Manchuria, produces enormous quantities of small fruit, an abundance of seed, and the fruit, owing to its poor quality, sells for a low price. Quantities of this seed would therefore be available at a reasonable price. But since the parent variety and also its seedlings are susceptible to blight, it is probably worthless as a source of seed. The temptation will be great for unscrupulous Chinese seed collectors to substitute this seed for the more expensive seed of desirable varieties.

It is evident from the foregoing discussion that it will be difficult and often impossible to procure quantities of desirable seed of *P. ussuriensis* from the Orient. In fact, the writer, who has had a wide experience in collecting and purchasing seeds in China, realizes that so far as this species is concerned it is difficult and perhaps a hopeless task to procure desirable seed through the Chinese dealers.

Extensive work is being done at the Experiment Station testing out seedlings of the most promising species to determine which are most suitable for stock purposes. Seedlings of Ba Li Hsiang, Guar Li and Man Yuan Hsiang were top-grafted with the leading commercial varieties of Oregon. This was done in 1919, hence the trees are now six years old. All the varieties have made an excellent growth, although there is some variation within each variety, due to differences in vigor in the seedlings. The trees on these seedlings of *P. ussuriensis* varieties average larger than those on French pear seedlings. The unions of Anjou, Bartlett, and Bosc are perfect on this stock. The Howell and Winter Nelis unions are also good, although in each of these varieties the scion has outgrown the stock slightly in several of the trees. These differences are slight, and immaterial at the present time. Whether the difference will ultimately become too great to be satisfactory remains to be determined. These trees were grafted from one to two feet above the ground where the scion more often outgrows the stock than at or below the surface of the ground. The Comice has outgrown the *P. ussuriensis* stock, and in many cases this difference is so pronounced that the union must be considered very unsatisfactory, and it is apparent that eventually the tree will either become seriously stunted or break off at the graft union. Hence, Comice should not be top-worked on *P. ussuriensis*.

As has already been indicated the most desirable tree is one with a resistant trunk and framework as well as a resistant root system. To produce such a tree it is necessary to graft a resistant variety onto the rootstock and later top-work this with the desired commercial variety, as described under *P. calleryana*. Some growers have used the seedlings of *P. ussuriensis* for both root and body stocks. Since many of the seedlings are susceptible to trunk blight and many of them develop an undesirable framework they should not be used for body stocks.

Some of the vigorous, blight-resistant strains of *P. ussuriensis,* however, may prove satisfactory trunk and framework stocks. These should not be used until it has been fully determined that they are perfectly hardy in the locality in which they are to be planted. The winter injury experienced during the past winter on the trunks of some varieties of this species proves that some of them—notably Chieh Li, Hsiang Sui, Hung Guar, and Ta Suan —should not be used as trunk stocks. Certain seedlings of Ba Li Hsiang have proved hardy and vigorous as well as immune to blight, and these are being tested as body stocks and may prove valuable for this purpose. Such strains, of course, must be propagated by budding or grafting.

Fig. 33. Fruit of Hung Guar, a cultivated variety of *P. ussuriensis.* Tree immune to blight. Fruit of poor quality.

Until we have further evidence regarding the value of these strains of *P. ussuriensis* as body stocks, it will be safer to use some of the most resistant French or American varieties for this purpose, such as Old Home, Variolosa, and Farmingdale. In our stock orchard most of the Old Home trees have made excellent growth on *P. ussuriensis* rootstocks, part of them being larger than the same variety on French stock, some of them of the same size, and some being smaller. It is unfortunate that the seedlings of even the best varieties of *P. ussuriensis* vary in vigor to this extent. If all of the *P. ussuriensis* seedlings were as strong growers as the most vigorous of them,

this would be a highly desirable rootstock. Such uniformly vigorous trees can be obtained in this species only by selecting the most vigorous seedlings in the nursery, and also by propagating selected seedlings from root cuttings as described on page 31 and 33.

For fruit. In Manchuria varieties of *P. ussuriensis* are extensively cultivated for their fruit; in fact, the leading varieties of southern and central Manchuria are either pure *P. ussuriensis* or hybrids of this species. There these varieties are very productive and the fruit of some of them is of good quality. The fruit is usually small to medium in size, tender fleshed and juicy, with a spicy, subacid flavor. The best flavored of these varieties in China are Hsiang Sui, Tang Li, Chien Pa, and Man Yuan Hsiang. The following rank as "poor" in flavor: Ba Li Hsiang, Chieh Li, Chiu Tze, Hua Kai, Huang Hsiang Sui, Hung Guar, Lo Suan, Nan Li, Mien Suan, Ping Li, Ta Mo Pan, Ta Suan, and Ta Tou Huang.

Some of these varieties, such as Pai Li, Hsiang Sui, and Tang Li, may prove of value for their fruit in certain parts of the United States where it is difficult or impossible to grow the better flavored American or European varieties. The fruit of most of these, however, is too small to be of commercial importance and cannot compete with the larger and better flavored fruit of the American varieties.

For breeding purposes. The writer believes that *P. ussuriensis* will prove more valuable in breeding work than for any other purpose. For many years horticulturists engaged in breeding work have been searching for a blight-resistant pear to be used as one of the parents. Until *P. ussuriensis* was introduced into this country no such blight-resistant variety was known. Furthermore, the earliest introductions of *P. ussuriensis* were all seedlings and produced very small, inferior fruit, identical with the wild fruit produced by this species in the Orient.

Attention has already been called to the fact that several of the varieties belonging to this species are highly resistant to blight and fortunately, some of these are the finest flavored varieties belonging to this species. The most promising of these are Hsiang Sui, Tang Li, and Chien Pa. The fruit of these varieties is small, pear shaped, with tender, juicy flesh and attractive, refreshing, subacid flavor. At this Experiment Station these varieties are being crossed with our best flavored American varieties, such as Bosc, Anjou, Bartlett, and Comice. This work was started in the spring of 1921 and has been very much extended during the past three years. The trees resulting from the 1921 crosses were inoculated with blight in 1924 and 21 percent proved immune. These have not borne any fruit up to the present time. We hope that a few seedlings will result from these crosses which will combine the desirable characteristics of both parents, such as immunity to blight, vigor, productiveness, large size, and fine flavor, as well as good keeping, shipping, and marketing qualities. The writer believes that it is only a question of time when such seedlings will be produced. It is, of course, well known that as soon as one such tree is obtained it can be very rapidly propagated and kept true to type by budding or grafting. It is reasonable to believe that this eventually will be the solution of the pear blight problem. The writer is convinced that the material now available for such breeding work is far superior to any that has heretofore been used by pear breeders.

PYRUS BETULAEFOLIA

Native habitat. *Pyrus betulaefolia* is widely distributed throughout northern and central China. The writer found it in many places, from the Great Wall in northeastern China to the Yangtze river, and from the sea coast to a point one thousand miles inland and at an elevation of four thousand feet. It probably does not extend very far south of the Yangtze river. It has never been reported from any part of Japan or Korea.

Fig. 34. Fruit of Pai Li, a *P. ussuriensis* hybrid. Finest flavored variety grown in northern China. Tree remarkably resistant to Pear Blight, although not immune. Valuable for breeding purposes.

Description. *P. betulaefolia* produces a tree medium to very large in size, usually from forty to sixty feet in height, with a trunk diameter of one to two feet and, rarely, as great as three feet. It is a vigorous but straggly grower, usually with horizontal or drooping branches. Some seedlings are thorny and others thornless. The young shoots are covered with a dense, light gray pubescence. On old trunks the bark is deeply checked and furrowed. The leaves are very characteristic and distinct from those of all other species. They are of medium size, lanceolate, with wedge-shaped base and long, tapering apex, margins coarsely serrate, light grayish-green color, and

usually densely covered with grayish pubescence. The blossoms appear late, are very small and are produced in great abundance in dense, pubescent clusters; stamens usually from eighteen to twenty; generally two, and rarely, three pistils. The fruit, which is borne in clusters of from five to ten, is smaller than that of any other species, varying from one-fourth to one-third inch in diameter, round, brown and russeted; flesh greenish, usually free from grit cells, a characteristic readily distinguishing it from that of *P. calleryana.* There are usually two and rarely three seed cells and one or two seeds in each cell. The seeds are very small and dark brown or grayish-black in color.

Introduction into the United States. The largest and oldest tree of this species which the writer has been able to locate in this country was planted at the Arnold Arboretum in 1882. This was grown from seed received from Dr. Bretschneider, then living at Peking, China. The tree is approximately thirty feet in height and has a trunk diameter of about one foot. It has proved perfectly hardy at the Arboretum.

Prof. N. E. Hansen, of the South Dakota Experiment Station, imported trees of this species from a nursery in Germany in 1896, and it is a remarkable fact that these trees have proved hardy in that cold climate. Various lots of seed of this species were collected in different places in northern China and sent to this country by the late Frank N. Meyer of the United States Department of Agriculture. A quantity of seed was collected by the writer in northern and central China in 1917 and 1919, and thousands of plants have been grown from these seeds at this Experiment Station. We have found that *P. betulaefolia* hybridizes readily with other species. A large percentage of the seed collected from trees growing in or near orchards containing varieties of *P. ussuriensis* and *P. phaeocarpa* is hybridized with these species. Such hybrid seedlings can be readily distinguished by both leaf and fruit characteristics. Seedlings grown from seeds all of which were collected from one tree often show remarkable variations, due to being hybridized with different varieties or even different species. When pure the seedlings are very uniform and by their light gray color can be distinguished from all other species at a considerable distance.

Susceptibility to Pear Blight. The results of the blight inoculation work given in Tables I and II of this bulletin show that *P. betulaefolia* is more susceptible than any other Oriental species except *P. phaeocarpa,* and very nearly as susceptible as *P. communis* in the tips and trunks. This species is far more resistant to blight in the roots than in the tips, and the roots are more resistant than those of the French seedlings. Eighteen of our trees of *P. betulaefolia* proved immune and these trees may become very valuable as the parents of rootstocks, since this species propagates more readily from root cuttings than any other.

As a stock. The fruit of *P. betulaefolia* is about the size of a garden pea and of no value, hence this species promises to become of economic importance only as a stock for other pears. In northern China it is extensively used as a stock for the cultivated Chinese varieties and has proved very satisfactory for that purpose.

In our stock orchard the six leading commercial varieties of Oregon are being tested on this species. The trees were grafted from twelve to eighteen inches above the ground and are now six years old. They have made a very satisfactory growth, slightly surpassing in vigor the same varie-

ties on the standard French pear stock. All the Bartlett and Anjou trees and part of the Winter Nelis have made perfect unions with this stock. But part of the Winter Nelis and all the Bosc and Howell trees are slightly larger than the stock just below the union. If this difference never becomes greater than it is at present the union will prove entirely satisfactory. The Comice, as is characteristic of this variety on all stocks when worked above the ground, is considerably larger than the stock. Whether this difference will finally become so great as to impair the rapid flow of sap and ultimately cause the union to become so weak as to prove unsatisfactory remains to be determined. The only safe plan to follow is to graft this variety at or below the surface of the ground. When *P. betulaefolia* is used as a stock the Bosc, Howell, and Winter Nelis should be grafted in like manner for

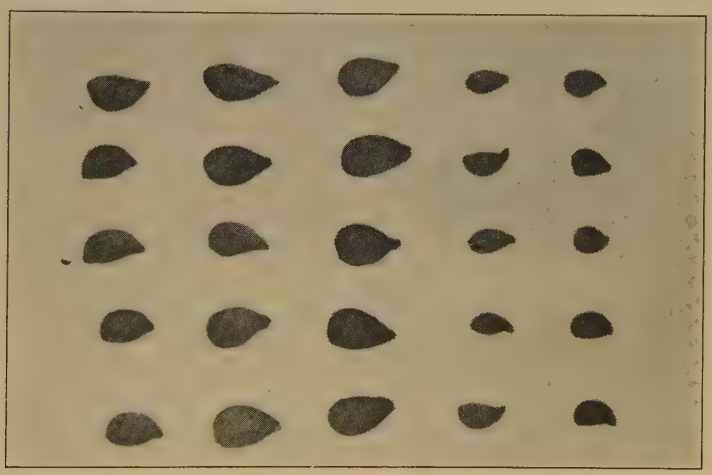

Fig. 35. Seeds of the five leading species of pears. Reading from left to right: *P. communis, P. serotina, P. ussuriensis, P. betulaefolia,* and *P. calleryana.* Note that the seeds of *P. betulaefolia* and *P. calleryana* are very much smaller than those of the other three species.

best results. As would be expected, the difference in size between stock and scion is considerably greater in some trees than in others of the same variety, due to the difference in vigor and size of the *P. betulaefolia* seedlings. By selecting only large, vigorous, rapidly growing seedlings of this species for stocks, perfect unions with our commercial varieties will result, especially when worked at the surface of the ground.

In another stock orchard Old Home was budded onto *P. betulaefolia* seedlings at the surface of the ground. In this case the unions are all perfect and the trees have outgrown those of the same variety on the French seedlings.

As in *P. calleryana,* the root systems of the different seedlings of this species vary tremendously in habit of growth. Most of them strike deeply into the ground and this enables the trees to endure severe droughts. Part of them have a well branched root system, but a larger percentage than in any other species possesses only long, unbranched tap-roots when not transplanted. By cutting back the tap-roots and transplanting the seedlings when

one year old, a well branched root system can be developed in all of them. Such transplanting is more important with *P. betulaefolia* and *P. calleryana* than with any other species.

Resistance to insects. *P. betulaefolia* is highly resistant to Pear Woolly Aphis. While it is not immune, the occurrence of this insect on this species is so rare and it is present in such small numbers on any infested tree that it causes no injury whatever.

Resistance to Leaf Blight. Near Washington, D. C., *P. betulaefolia* has proved highly resistant to Leaf Blight.[1] In that locality this disease is very abundant on and destructive to the French and Japanese pear seedlings, often defoliating them by mid-summer.

Soil adaptations. The writer found this species growing in a great variety of soils in the Orient, varying from coarse sands to heavy clays; and from high, dry, droughty hillsides to low, flat, swampy places. It is really remarkable that a species of pear will endure some of the adverse soil and moisture conditions under which this one is found in northern and central China. In the Ho Nan Province it is often used as a wind and sand break in the sand and alkali regions where very few other shrubs and trees thrive. In a cooperative test now in progress in California, young trees are flourishing in some alkali soils in which all French, Japanese, and *P. ussuriensis* seedlings were killed.

Judging from observations in the Orient and also from the behavior of trees growing on sandy and gravelly spots at this Station, it is likely that this species will endure drought better than any other Pyrus. This is probably due to the habit the roots possess of growing down to a great depth in such soils. It has been observed that the leaves of *P. ussuriensis* often wilt and sunburn on gravelly spots where *P. betulaefolia* flourishes.

It seems remarkable that a tree which can tolerate such droughty conditions should also be able to endure very wet, swampy soils, but this appears to be true. It is, of course, quite possible that we may find great variation within the species and that some seedlings and some root systems will be far better adapted to wet soils than others which may be admirably adapted to very dry soils. If this proves to be the case the two types should be segregated and one propagated for wet and the other for very dry soils.

Climatic requirements. This species is found wild from northern China where the winters are dry and very cold, to the Yangtze River in central China, with its mild winter climate, where certain semi-hardy oranges are successfully grown. In the north it extends to the southern limit of *P. ussuriensis*. It has never been reported from central or northern Manchuria, but undoubtedly occurs in extreme southwestern Manchuria. In the United States it has proved hardy at Ames, Iowa, and Brookings, South Dakota.[2] It appears to be perfectly at home in the dry summer climate of Southern Oregon, and is doing well in the hot, dry climate at the Plant Introduction Garden at Chico, California.

Judging from observations made in China and in this country, it appears probable that this species will succeed over a greater area in the United States than any other Chinese species. It may prove as well adapted to the Gulf Coast states as *P. calleryana*. It is unquestionably a remarkable species and should be widely tested in this country.

For breeding purposes. Since the fruit of this species is very small and practically inedible, and a high percentage of the trees are susceptible to blight, it offers far less to the pear breeder than does *P. ussuriensis.* It has been used by Professor N. E. Hansen of South Dakota in some of his crosses with American varieties, and since certain seedlings of this species are hardy there, it may prove of value in producing hardy new varieties for very cold climates.

PYRUS SEROTINA

Pyrus serotina is a native of central and western China and central and northern Japan. Some botanists are of the opinion that it was not originally native to Japan, but was introduced there from the eastern part of China. The writer believes that it is a native, since he found the species widely distributed throughout central and northern Japan, where it is wild and appears to be perfectly at home. It is quite probable that the seeds of this species were carried there from China by birds long before the advent of man. The writer found it in the upper Yangtze River Valley, and Mr. E. H. Wilson[5] of the Arnold Arboretum found it in various places in central and western China. It therefore flourishes in regions having a very heavy summer rainfall and comparatively dry winters. The writer has never found it wild in northern China or Manchuria.

Description. The tree is a very vigorous grower, attains great size and age, and is very productive. The young shoots have a glossy green bark which becomes darker with age and on the old trunks is deeply furrowed but never checked like that of *P. ussuriensis.*

The leaves are very large, ovate-oblong, with long tapering point, rounded or sub-cordate base, and coarsely setose-serrate margins; when young they are often pubescent, but on most seedlings soon become glabrous. The tree foliates and blooms early in the spring, but not as early as *P. ussuriensis.* The blossoms are borne in loose clusters of five to eight, are large, white, with five and occasionally six to ten large oval petals, and usually eighteen to twenty and rarely twenty-five to thirty stamens, and five pistils.

The fruit is usually round or slightly flattened, from three-fourths to one and one-quarter inches in diameter, of a brownish russet color, and borne on a long stem. The calyx is variable, usually deciduous, but often partly or wholly persistent. The flesh is hard and contains many grit cells, particularly around the core, and has a sweet or insipid flavor, never equalling the finest varieties of *P. communis* or the best varieties of *P. ussuriensis.* The core is five celled with two large dark brown or black seeds in each cell. There is great variation in the character of the calyx. On some trees all of the fruits have a deciduous calyx, while on others the various fruits have from one to five of the lobes persistent. Some botanists hold the opinion that those forms having an entire or partial persistent calyx are hybrids between *P. serotina* and some other species.

Introduction into the United States. *Pyrus serotina* was brought to this country earlier than any other Oriental species. The first importation was that of the Chinese Sand pear, obtained in England and brought to this country in 1840 by William Prince of Flushing, New York. Since then it has been brought to this country at various times by sea captains, missionaries, and others. During the past thirty-five years large quantities of seeds and seedlings have been imported into the United States and propagated for stock purposes.

P. serotina has been popular with nurserymen in the southern states and on the Pacific Coast. In the South it is usually less susceptible to leaf blight and far more vigorous than the French stock. In the southern states and on the Pacific Coast it is, at this time, more widely used for stock purposes than the French pear. In the northeastern states, more particularly in New York and New England, it is not as popular or valuable as the French stock, due probably to lack of hardiness. This stock is not as hardy as the French, hence should not be used in the colder portions of this country. It has given rise to a number of cultivated varieties which seem to be better adapted to the southern states than any of the European varieties.

Resistance to blight. From time to time it has been observed by pear growers, particularly in the southern states, that some of the seedlings of these so-called Japanese pears were much freer from pear blight than the French varieties. The inoculation results reported in Table II show that this is an extremely variable species, ranging from highly resistant varieties to those which are very susceptible. Among all the trees inoculated only four have proved immune in all parts of the tree, although many others have blighted only in the young shoots. It is far more susceptible in trunks and roots than *P. calleryana* and *P. ussuriensis,* only slightly more resistant in the roots than *P. betulaefolia,* but is much more resistant in trunks and roots than the French seedlings.

This species is not as resistant to the Mushroom Root Rot as the French pear stock. The writer has observed a number of trees which were attacked by this disease, and several cases have been reported from the state of California. Hence, this stock should not be used on soils which are known to be infested with Mushroom Root Rot. The fact that *P. serotina* is susceptible to this disease, and also that it is sensitive to wet soils, will eliminate it from many Pacific Coast plantings.

Resistance to Woolly Aphis. The Japanese seedlings are far more resistant to Pear Woolly Aphis than the French pear stock. In general, it can be said that this insect is not a serious pest on this stock; occasionally young seedlings are dug in the nursery which are thoroughly infested with Woolly Aphis, but these cases are rare. The species, however, is not nearly as resistant to this insect as *P. calleryana, P. betulaefolia,* or *P. ussuriensis.*

As a stock. *P. serotina* has been used as a stock in the United States much longer than any other Oriental species. It has been extensively propagated and distributed, and we now possess evidence relative to its merits as well as its limitations. Up to the present time it has been most satisfactory in the mild climate of the southern states and on the Pacific Coast, and apparently will always be more useful in those regions than in other sections of this country.

The pears which are most widely grown on the Pacific Coast, such as Bartlett, Bosc, Anjou, Winter Nelis, Howell, and Comice, are very easily and successfully propagated on this stock. The buds and grafts unite readily, make a good strong union and the stock maintains the same size as the scion when the union is formed at or below the surface of the ground. These trees are equally as vigorous as those on French pear stock and in some cases more vigorous. Old Home and Variolosa make good unions with this stock and the trees are vigorous, but not equal to those on *P. calleryana.* In our work at this Station it has been demonstrated that practically all of the known species of Pyrus can be propagated on *P. serotina.* All of these spe-

cies bud readily, make a strong union and grow very satisfactorily on this Japanese stock. The poor stand of buds often obtained on this stock in New York state is probably due to winter injury. Such winter injury was especially abundant at this Station in 1924, when most of the buds of our standard varieties died because a small area on the Japanese seedlings, immediately around the inserted buds, was killed. The remainder of the seedling was not injured. The opening made on the seedling in budding permitted winter injury at this point.

Soil adaptations. While *P. serotina* can be successfully grown on a variety of soils, it is not as cosmopolitan as the French stock. As it becomes more widely distributed we are learning that it has certain limitations. On the Pacific Coast it appears to be equally as satisfactory as the French stock on deep, mellow, and well drained soils. On shallow and wet soils it is not satisfactory. Under such adverse conditions the young trees grow vigorously for a number of years, but when the trees are from ten to fifteen years old they become stunted and unsatisfactory. The French and *P. calleryana* stocks will give far better results than the Japanese seedlings on such soils. *P. serotina* will not endure soils containing alkali or an excess of lime. On soils of this character *P. betulaefolia* will prove more satisfactory as a stock.

Whether the trees of our standard American varieties will prove as long lived on this stock as on the French, remains to be determined. This point can be finally decided only after many more years of observation.

The Japanese seedlings usually develop a strong and well branched root system. Some of the seedlings, however, have a tendency to produce two or three prong roots which strike deep into the soil and possess very few lateral roots. This tendency to produce a deep root system is more pronounced than in most of the French seedlings. It is a valuable characteristic on deep, mellow, well drained soils, but is objectionable on shallow soils underlaid with tenacious or tight clay subsoils, or with hard-pan or bed-rock. From this it is evident that the trees should be transplanted in the nursery at least once in order to develop a better branched root system.

For top-working. The Japanese seedlings cannot be recommended as trunk and body stocks for top-working purposes. There is too much variation in the seedlings; most of them are exceedingly spiny and few possess a desirable framework for top-working. In other words, the branches do not grow in the upright, spreading manner which makes a clean, vigorous growth at a desirable angle for top-working. Among the hundreds of tested seedlings of this species one has been found which is immune to blight and the framework develops a desirable form. This will be thoroughly tested and if it makes a good union with our cultivated varieties it will prove valuable as a body stock. This type must, of course, be propagated by budding or grafting.

For breeding purposes. *P. serotina* crosses readily with the American varieties and will undoubtedly prove of greatest value in the pear breeding work in our southern states. It is one of the parents of Kieffer and related varieties which have proved valuable in the southern states. There it appears to be perfectly at home, because the climatic conditions, at least during the summer months, are similar to those of central China; the tree is much freer from insects and various diseases, and far more productive than the French pears. At present it appears to be the most promising of all the Oriental

types for pear breeding in that region. It is probable that in the northern states and on the Pacific Coast *P. ussuriensis* will be of more value for breeding purposes than *P. serotina.*

MINOR AND DOUBTFUL SPECIES

Five other Chinese species of Pyrus which have shown a fair degree of resistance to blight should be mentioned here. These apparently are not as valuable as the foregoing species, but since they are natives of the Orient and may be confused with the more valuable species by seed collectors, and are not well known in this country, it will be well to enumerate briefly their chief characteristics.

PYRUS SERRULATA

The type which Mr. Alfred Rehder has designated as *P. serrulata*[5] is a doubtful species. This appears to be a group of hybrids. It will facilitate the discussion in this publication, however, to retain this specific name.

Description. As it grows in central China, the type is intermediate between the two species, *P. serotina* and *P. calleryana.* The leaves are very similar to those of *P. calleryana,* but slightly longer. The fruit is brown in color, like the two parent species, but intermediate in size and number of core cells—usually three or four. The seedlings grown from seed collected by the writer in central China are extremely variable, ranging from types identical with *P. calleryana* to those typical of *P. serotina.* In China it has been found only in a region in which both *P. calleryana* and *P. serotina* occur. For these reasons the writer considers this a group of hybrids between these two species. If it is a distinct species it hybridizes very readily with both *P. calleryana* and *P. serotina.*

Mr. E. H. Wilson of the Arnold Arboretum found this type growing in the mountains west and southwest of Ichang in central China, and the species was based on the material which he collected. So far as known at the present time, it is not very widely distributed.

Inoculation results. The results obtained from our inoculation work with this species were presented in Table I. These results show as great variation in the seedlings as that displayed in the botanical characteristics. A number of the types are highly resistant, a few immune, and some are very susceptible. Slightly more than 40 percent of the trunk inoculations developed heavy infections. It is therefore far more susceptible than *P. calleryana.*

An interesting type in our collection, belonging to this species, is one which Mr. Wilson introduced as Serrulata No. 479. This type has been propagated by budding, and since it may prove valuable as a body stock the inoculation results have been reported in Table V. At this Experiment Station it has proved a vigorous grower and in leaf and fruit characteristics it is intermediate between *P. serrulata* and *P. betulaefolia.* This tree has been in bearing for five years and has never shown any natural infections, although it is growing in the midst of other varieties which blight readily. This tree has been inoculated many times during the past nine years; most of the inoculations on the trunks and large branches have failed, while the re-

mainder have produced only small superficial bark cankers. Many inoculations made in the tips of young and succulent shoots have been successful, but the infections have always been confined to the small growths, never extending into wood more than one year old. The disease usually extended down the young shoot for only a few inches. This tree has been heavily pruned, is growing on very fertile soil, and has been thoroughly cultivated and irrigated in order to make it as susceptible as possible to pear blight.

Since the seedlings are so variable and a much larger percentage of them are susceptible to blight than in *P. calleryana,* they cannot be recommended as blight-resistant stocks. Some of the immune trees may prove valuable when kept true to type by propagating from root cuttings. Some trees of this species appear promising as trunk and framework stocks. These particular trees are immune to blight and are vigorous growers. Unfortunately, none of our standard varieties have been top-grafted to this type, hence we cannot say whether the union will prove congenial. Serrulata No. 479 makes a very slow growth in the nursery on all the stocks, but grows vigorously when transplanted to the orchard.

Soil and climate. In the region in which *P. serrulata* has been found in China the climate is hot and damp in summer and mild and comparatively dry in winter. Just how low the temperature goes during the winter months is not known, but it is probable that it is never lower than zero. At this Experiment Station two-year-old seedlings withstood a temperature of ten degrees below zero without injury, and the species appears to be hardy near Boston, Mass.

Little has been done to determine soil adaptations and requirements of this type. It grows splendidly on a fertile, deep, silty clay loam soil at this Station, and in the mountains of China it was found on a variety of clay and sandy loams. The writer observed it only in the mountains and always on soils that were well drained. It cannot be recommended as a stock for extensive commercial planting until it has been thoroughly tested in an experimental way.

PYRUS BRETSCHNEIDERI

This form was given specific rank[5] by Mr. Alfred Rehder, and his description was based on a single tree growing at the Arnold Arboretum, which was obtained from seed collected near Peking, China, in 1882.

Description. The tree is a vigorous, upright grower with slender and very dark, glossy branches. The leaves are large, elliptical or elliptical-ovate, with acuminate apex, broad wedge-shaped base, and coarsely setose-serrate margins. The fruit is borne on long, slender peduncles, is round, yellow, three-fourths inch in diameter, with a deciduous calyx. The flesh is white, firm, juicy, with few grit cells, and a mild subacid flavor. The core is three or four celled.

The writer is inclined to believe that this is not a distinct species. In his extensive travels in northern China and particularly in the region around Peking, he found only four trees which could be placed in this group. These, however, were in some respects quite distinct from Mr. Rehder's type and from each other. They were similar only in having round or slightly oval fruit, yellow in color, with a deciduous calyx. There was great variation in the leaf, branch and growth characters. The fruits also vary in size, being one-fourth to three-fourths of an inch in diameter.

The writer is strongly of the opinion that these are hybrids, *P. ussuriensis* being one of the parents. One type has leaves closely resembling those of *P. ussuriensis,* and while the fruit is greenish-yellow, like that of *P. ussuriensis,* the size is identical with that of *P. betulaefolia* and like that species has a deciduous calyx. *P. ussuriensis* has probably entered into all of these crosses, but in some cases it is difficult to determine the other parent. In three instances it appears to be *P. betulaefolia.*

The types which the writer found were in the mountains from seventy-five to one hundred miles northeast of Peking. In all instances the trees grew in or near cultivated orchards containing a number of varieties, principally *P. ussuriensis.* In this region *P. betulaefolia* and *P. phaeocarpa* are also found. It is strange that this species is so extremely rare in the locality where it is supposed to be native, while other well established species are very abundant there.

The notes made by the late Frank N. Meyer, explorer for the United States Department of Agriculture show that in his extensive explorations in China he rarely met with this type, and the few trees were isolated specimens.[3] The trees are among the most vigorous of the Chinese pears, but are very shy bearers, thus indicating hybridity.

Inoculation results. From 1915 to 1919 our inoculation work with this species was confined to the one form obtained from the Arnold Arboretum. Since the spring of 1920 two of the types collected by the writer in China have been included. This work has been restricted to that portion of the tree above ground, no root inoculations having been made.

The Arnold Arboretum type is not immune to pear blight, but has shown a moderate degree of resistance in the larger wood. The disease has usually appeared only in the smaller shoots and very rarely entered the larger branches. In a few instances, however, infection has been obtained in wood two inches in diameter, and in one case a serious infection occurred in a trunk slightly more than three inches in diameter. No natural infections have been observed in any of these trees. One of the types collected by the writer has shown a very high degree of resistance. Most of the inoculations have failed entirely, and in the small number of successful ones the disease has confined itself to very young shoots. In no instance have we been able to kill a tree one or more years of age.

This type produces fruit a quarter of an inch in diameter, usually two and rarely three celled, and the flesh is free from grit cells. The size of the fruit and number of core cells is typical of *P. betulaefolia,* while the color of the fruit is yellow, in this respect resembling that of *P. ussuriensis.* It is evidently a hybrid between these two species.

Economic value. Due to its vigor, freedom from spines and high resistance to blight, one of these types may prove of value as a trunk and framework stock for top-working. Apparently the seedlings are too variable to be desirable for rootstocks. When used for trunk stocks this type should be propagated by budding or grafting on a desirable root system, such as cultivated *P. ussuriensis,* or some other promising species.

PYRUS OVOIDEA

Botany. Mr. Alfred Rehder based this species[5] on one tree at the Arnold Arboretum which was obtained from the Kew Botanical Gardens, as *P. simonii.* The writer never found this type growing wild in China, and

does not believe that it is a distinct species. It is probably a subspecies or hybrid of *P. ussuriensis*. It is notable that in the writer's extensive explorations in China, where a careful search was made for it, not one wild tree of this species was found. One of the cultivated pears in southwest Manchuria, Chiu Tze, resembles this form very closely in fruit characters and has leaves which are typical of *P. ussuriensis*.

Description. *P. ovoidea* is a very vigorous grower, with long spreading branches. It is free from spines and in that respect differs from the wild type of the well known species of Pyrus. The color of the bark is distinctly yellowish, resembling *P. ussuriensis*. The leaves are very large and thick, ovate-elliptical, with acute apex and coarsely serrate-setose margins.

The fruit, about one inch in diameter, is ovoid in shape, with a long peduncle and persistent calyx. The flesh contains comparatively few grit cells and is white, firm, juicy, and edible. The flavor is sweet but not attractive. The flowers are large and the tree blooms early, closely following *P. ussuriensis*.

Habitat. If this is a distinct species, its native home in China is unknown, as the wild type has never been found by any collector. It is undoubtedly a native of the extreme north, since the tree is remarkably hardy in this country, notably as far north as Brookings, S. D. Since it is probably a strain or hybrid of *P. ussuriensis*, its native habitat is doubtless identical with that of the parent species.

Resistance to blight. The inoculation results presented in Table I show that this species is very resistant to blight, especially in the older wood. Only 4.8 percent of the trunk infections were classed as heavy, and these were in young trees. This is only a fraction more than the percentage of heavy infections shown by the wild *P. ussuriensis*. It must be borne in mind that all the inoculation work with *P. ovoidea* was done with one type. Most of the trunk inoculations have failed entirely. In some cases small cankers have been produced, but in no instance has a canker completely girdled the trunk or even a branch which was an inch or more in diameter. These cankers have usually been superficial, rarely destroying all of the bark to the sap-wood and in nearly every instance the disease died out naturally and the wound healed over completely from the live tissue underneath. In the young shoots the disease will run from a few inches to two feet, but rarely extends into wood more than one-half inch in diameter, and the type may be regarded as highly resistant.

Economic value. This type has not been used as a rootstock, since few seedlings have been available. While it is very vigorous, it cannot be considered desirable for top-working, since the branches do not make a desirable rigid, upright growth. It is quite probable that its greatest value will be for breeding work. Prof. N. E. Hansen of Brookings, S. D., has used *P. ovoidea* in some of his pear breeding work and sent us a hybrid between this species and Clapps Favorite, which he has named Tolstoy. With us this is a vigorous upright grower, with desirable habit of growth, and it has shown a very high degree of resistance to Pear Blight. During our five years of inoculation work with it all of the inoculations on the trunk and most of those on the larger branches have failed. Only two small superficial cankers have developed on branches an inch or more in diameter and in these the disease made comparatively little headway, never reaching the sap-wood. In

the young succulent branches the inoculations often failed. In some cases the shoots were killed back a distance of twelve to twenty-four inches, but the infection never extended into wood more than one-half inch in diameter. These trees have been very severely pruned, thoroughly cultivated, on rich soil and are growing among other trees seriously affected by the disease. The tree makes a slow growth in the nursery but becomes vigorous as it grows older in the orchard. No top-working has been done on this hybrid, but judging from its high resistance to blight and its clean, vigorous growth, resembling *P. communis* in some respects, it will probably become valuable as a stock for top-working. We shall thoroughly test it for this purpose in the near future. The fruit produced by this hybrid is very poor in quality.

It should not be inferred from the foregoing that all of the hybrids of this species will be equally resistant to pear blight. Professor Hansen's cross between this species and Parrot, which he has named Gogol, has blighted quite seriously in our inoculation experiments and for that reason has been discarded.

PYRUS KOEHNEI

This species is a native of the tropical and semi-tropical parts of extreme southern China. It occupies a position there similar to that of *P. calleryana* in central China. As a matter of fact, in tree, leaf, and external fruit characters it is similar to *P. calleryana.* It possesses three or four pistils and core cells, and these are the only characters by which it can be distinguished with certainty from *P. calleryana,* which usually possesses only two and rarely three.

Since this species is a native of extreme southern China, it is practically an evergreen, the old leaves falling just before the new ones appear. Even here in Southern Oregon the leaves remain on the tree and are green all winter. During an average winter this type is not materially injured here, but in severe winters the trees are badly killed back. At a temperature of ten degrees below zero, all of our trees were killed down to the snow line, although the roots remained in perfect condition.

The introduction of this species into the United States was comparatively recent. The only large trees of which the writer has knowledge are five at Oroville, California. These were grown from seeds collected near Canton, China, and shipped to California in 1908 by Mr. G. Compere, of the California State Board of Horticulture. The identity of the species was not known in this country until the writer classified it[7] in the fall of 1915. It has attracted considerable attention because the trees at Oroville have been comparatively free from both blight and Pear Woolly Aphis, while other varieties near these trees have suffered severely from this disease and insect.

In the inoculation work at this Station this species was easily infected in the young wood and the branches were readily destroyed. It has shown a high degree of resistance in the larger wood and especially in the root system. In Southern Oregon it is not a very vigorous grower and is not sufficiently hardy to be recommended.

Economic value. Trees of this species were budded in the fall of 1916 with our leading commercial varieties. These have made a vigorous growth, although not equal to those on *P. calleryana.* Up to the present time, the unions have been entirely satisfactory.

P. koehnei may prove valuable as a stock in very warm regions and should be thoroughly tested in the southeastern United States and particularly on the Gulf Coast. Judging from Mr. Compere's observations, it will prove valuable on wet soils and on those with a high water table. He found it growing vigorously in swamps near Canton, China, under conditions which would have been fatal to our American pears. This may be due to its shallow root system. The writer has observed that the roots have a tendency to spread out horizontally just below the surface of the ground.

The inoculation results presented in Table I show that this species is not as resistant to blight as *P. calleryana,* but more resistant than *P. serotina* and seedlings of most cultivated varieties of *P. ussuriensis.*

PYRUS FAURIEI

This is a native of southern and central Korea. In 1917 the writer made a thorough study of its distribution and characteristics in that country. This type appears to be the northern or Alpine form of *P. calleryana.* It is very similar to that species in nearly every respect except size of tree and leaves, which are very much smaller. In fact, the trees are usually mere shrubs or bushes and sometimes grow in thickets. In all respects the fruit is similar to that of *P. calleryana.*

This type is quite variable, some of the seedlings showing a high degree of resistance to blight and others marked susceptibility. It is apparently of little value as a stock, except possibly as a dwarfing form to take the place of the quince commonly used for this purpose.

RECOMMENDATIONS

The results obtained from our work have been fully presented in this bulletin and the characteristics of all important species and varieties have been discussed. It will, therefore, not be necessary to make any recommendations to those who have read these results and the discussion. Many years must elapse before we can gather sufficient information to enable us to pass final judgment on each species. As additional tests of the various types are made the merits and the limitations of each will become more apparent. The following are merely preliminary recommendations which probably will be modified as further information is accumulated.

Rootstocks. At the present time and for several years to come only seedlings will be available in commercial quantities for rootstocks. In each species some desirable and some undesirable seedlings will be found, although certain species produce a much larger percentage of desirable seedlings than others. Hence those species should be selected which produce the highest percentage of suitable seedlings for the particular locality under consideration.

P. calleryana appears to be the most desirable stock in localities where root blight is prevalent and the winter climate is mild, as in the Rogue River Valley of Southern Oregon. Until further evidence is available, this species should not be planted where the temperature goes lower than ten degrees below zero. Reliable seed of this species can be easily procured from China.

Seedlings of certain cultivated varieties of *P. ussuriensis,* particularly those of Ba Li Hsiang, are highly resistant to root blight and have made satisfactory rootstocks on deep, mellow, well drained soils. In regions too

cold for *P. calleryana* and where root blight is prevalent, the seedlings of these varieties, when grown on such soils, are likely to make the most satisfactory rootstocks. Only the most vigorous of these seedlings should be used. This stock should not be used on heavy wet soils.

In China the supply of seed of the most desirable varieties of *P. ussuriensis* is very limited and difficult to obtain. To be assured of dependable seed of this species America will have to produce its own supply.

The French seedling, *P. communis,* will prove highly satisfactory in regions where root blight and Pear Woolly Aphis are not prevalent, and in such regions it is probably the safest stock to use. It will give better results on very heavy, wet and shallow soils than any other species except possibly *P. calleryana.*

P. serotina, the Japanese seedlings, should be planted only where the soil is deep, well drained, and free from Mushroom Root Rot. It will prove unsatisfactory on wet and shallow soils and in cold climates.

P. betulaefolia should be used where the soil contains too much alkali for the French or *P. ussuriensis* stock. On such soil, however, our commercial varieties of pears will probably not prove profitable on any stock.

The best stock for the various distinct climatological districts can be determined only by experimentation within these districts.

The most valuable rootstocks are discussed on pages 60-90.

Trunk and framework stock. In localities where blight often destroys the trunk and body branches of susceptible varieties, such losses can be largely prevented by top-working on a resistant body and framework stock. The most promising varieties for this purpose which have been thoroughly tested in Southern Oregon are Old Home and Variolosa. These have shown a high degree of resistance to blight and make a strong and desirable union with the leading varieties grown here. Both are hardy in this region, develop a strong, well formed framework, and Old Home is the most vigorous grower in our entire collection. These varieties are budded or grafted on the most suitable rootstock at the surface of the ground. The one-year-old trees are planted in the orchard and grown for at least three years, during which time a well branched and symmetrical framework is developed. They are then top-worked in the branches with the desired commercial variety, as shown in Fig. 25.

Kieffer has been used as a body stock in Southern Oregon, and our leading commercial varieties make an excellent union with it when top-grafting is done on one-year-old wood. This variety, however, is not sufficiently resistant to blight to be employed as a stock. Furthermore, it is subject to winter injury.

Estella is highly resistant to blight in the larger wood and makes a good body stock for Bartlett and Anjou. It is not a congenial stock for Bosc.

Certain other varieties also appear very promising as body stocks and when thoroughly tested may prove equal or even superior to Old Home and Variolosa. Among these are Farmingdale, Tolstoy, Serrulata No. 479, and certain strains of Ba Li Hsiang.

Owing to the great variation in seedlings they should not be used for any portion of the tree above ground.

The most valuable body stocks are discussed on pages 42-48.

The fact should be emphasized that when a susceptible variety like Bartlett is top-worked on a resistant body stock like Old Home the Bartlett part does not become resistant to blight. In other words, the Bartlett portion of the tree will blight just as readily when it is infected as it will on any other stock. The chances of infection, however, are very materially reduced since there is no "hold over" blight in the resistant root and body stock.

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